REPORT

OF THE

EIGHTY-FOURTH MEETING OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE

AUSTRALIA: 1914

JULY 28—AUGUST 31

LONDON
JOHN MURRAY, ALBEMARLE STREET
1915

Office of the Association: Burlington House, London, W.

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LIST OF PLATES.

OFFICERS AND COUNCIL, 1914–1915.

PATRON.

HIS MAJESTY THE KING.

PRESIDENT.

Professor WILLIAM BATESON, M.A., F.R.S.

VICE-PRESIDENTS.

His Excellency the Governor-General of the Commonwealth of Australia.
Their Excellencies the Governors of New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania.
The Honourable the Prime Minister of the Commonwealth.
The Honourable the Premiers of New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania.
The Right Honourable the Lord Mayors of Sydney and Melbourne.
The Right Worshipful the Mayors of Brisbane, Adelaide, Perth, Hobart.
The Chancellors of the Universities of Sydney, Melbourne, Adelaide, Tasmania, Queensland, Western Australia.

PRESIDENT ELECT.

Professor ARTHUR SCHUSTER, PH.D., SEC.R.S.

VICE-PRESIDENTS ELECT.

The Right Hon. the Lord Mayor of Manchester.
The Right Hon. LORD SHUTTLEWORTH, LL.D., Lord-Lieutenant of Lancashire.
The High Sheriff of Lancashire.
The Right Hon. VISCOUNT MORLEY OF BLACKBURN, O.M., D.C.L., F.R.S., Chancellor of Manchester University.
His Grace the DUKE OF DEVONSHIRE.
The Right Hon. the EARL OF DERBY, K.G.
The Right Hon. the EARL OF ELLESMERE, M.V.O.
The Right Hon. VISCOUNT BRYCE, D.C.L., LL.D., F.R.S.
The Rt. Rev. the Bishop of Manchester.
The Chancellor of the Duchy of Lancaster.
The High Sheriff of Cheshire.
The Worshipful the Mayor of Salford.
The Right Rev. the Bishop of Salford.
The Right Hon. Sir H. E. ROSCOE, Ph.D., D.C.L., F.R.S.
The Right Hon. Sir WILLIAM MATHER, LL.D.
The Vice-Chancellor of the University of Manchester.
Sir EDWARD DONNER, Bart., LL.D.
Sir FRANK FORBES ADAM, C.I.E., LL.D.
Alderman Sir T. THORNHILL SHANN, J.P.
Professor HORACE LAMB, D.Sc., F.R.S.
R. NOTON BARCLAY, Esq.

GENERAL TREASURER.

Professor JOHN PERRY, D.Sc., LL.D., F.R.S.

GENERAL SECRETARIES.

Professor W. A. HERDMAN, D.Sc., F.R.S. | Professor H. H. TURNER, D.Sc., D.C.L., F.R.S.

ASSISTANT SECRETARY.

O. J. R. HOWARTH, M.A., Burlington House, London, W.

CHIEF CLERK AND ASSISTANT TREASURER.

H. C. STEWARDSON, Burlington House, London, W.

LOCAL TREASURER FOR THE MEETING AT MANCHESTER.

Alderman EDWARD HOLT, J.P.

LOCAL SECRETARIES FOR THE MEETING AT MANCHESTER.

Professor S. J. HICKSON, D.Sc., F.R.S. | Principal J. C. MAXWELL GARNETT, M.A.
Councillor E. D. SIMON, M.I.C.E.

ORDINARY MEMBERS OF THE COUNCIL.

ARMSTRONG, Professor H. E., F.R.S.	HALL, A. D., F.R.S.
BRABROOK, Sir EDWARD, C.B.	HALLIBURTON, Professor W. D., F.R.S.
BRAGG, Professor W. H., F.R.S.	IM THURN, Sir E. F., K.C.M.G.
CLERK, Dr. DUGALD, F.R.S.	LODGE, ALFRED, M.A.
CRAIGIE, Major P. G., C.B.	LYONS, Captain H. G., F.R.S.
CROOKE, W., B.A.	MELDOLA, Professor R., F.R.S.
DENDY, Professor A., F.R.S.	MYRES, Professor J. L., M.A.
DIXEY, Dr. F. A., F.R.S.	RUTHERFORD, Sir E., F.R.S.
DIXON, Professor H. B., F.R.S.	SAUNDERS, Miss E. R.
DYSON, Sir F. W., F.R.S.	STARLING, Professor E. H., F.R.S.
GRIFFITHS, Principal E. H., F.R.S.	TEALL, Dr. J. J. H., F.R.S.
HADDON, Dr. A. C., F.R.S.	THOMPSON, Dr. SILVANUS P., F.R.S.

WEISS, Professor F. E., D.Sc.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord RAYLEIGH, O.M., M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Sir ARTHUR W. RÜCKER, M.A., D.Sc., LL.D., F.R.S.
Major P. A. MACMAHON, D.Sc., LL.D., F.R.S., F.R.A.S.

PAST PRESIDENTS OF THE ASSOCIATION.

Lord Rayleigh, O.M., F.R.S.	Sir James Dewar, LL.D., F.R.S.	Sir J. J. Thomson, O.M., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.	Sir Norman Lockyer, K.C.B., F.R.S.	Prof. T. G. Bonney, Sc.D., F.R.S.
Sir A. Geikie, K.C.B., O.M., F.R.S.	Arthur J. Balfour, D.C.L., F.R.S.	Sir W. Ramsay, K.C.B., F.R.S.
Sir W. Crookes, O.M., Pres.R.S.	Sir E. Ray Lankester, K.C.B., F.R.S.	Sir E. A. Schäfer, LL.D., F.R.S.
Sir W. Turner, K.C.B., F.R.S.	Sir Francis Darwin, F.R.S.	Sir Oliver Lodge, D.Sc., F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.		

PAST GENERAL OFFICERS OF THE ASSOCIATION.

Prof. T. G. Bonney, Sc.D., F.R.S.	Sir E. A. Schäfer, LL.D., F.R.S.	Dr. J. G. Garson.
A. Vernon Harcourt, D.C.L., F.R.S.	Dr. D. H. Scott, M.A., F.R.S.	Major P. A. MacMahon, F.R.S.
Sir A. W. Rücker, D.Sc., F.R.S.	Dr. G. Carey Foster, F.R.S.	

AUDITORS.

Sir Edward Brabrook, C.B. | Professor H. McLeod, LL.D., F.R.S.

RULES OF
THE BRITISH ASSOCIATION.

[*Adopted by the General Committee at Leicester, 1907, with subsequent amendments.*]

CHAPTER I.

Objects and Constitution.

1. The objects of the British Association for the Advancement of Science are: To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers; to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress. **Objects.**

The Association contemplates no invasion of the ground occupied by other Institutions.

2. The Association shall consist of Members, Associates, and Honorary Corresponding Members. **Constitution.**

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee.

3. The Association shall meet annually, for one week or longer, and at such other times as the General Committee may appoint. The place of each Annual Meeting shall be determined by the General Committee not less than two years in advance; and the arrangements for these meetings shall be entrusted to the Officers of the Association. **Annual Meetings.**

CHAPTER II.

The General Committee.

1. The General Committee shall be constituted of the following persons:— **Constitution.**

(i) *Permanent Members*—

(*a*) Past and present Members of the Council, and past and present Presidents of the Sections.

(*b*) Members who, by the publication of works or papers, have furthered the advancement of knowledge in any of those departments which are assigned to the Sections of the Association.

(ii) *Temporary Members*—

(*a*) Vice-Presidents and Secretaries of the Sections.
(*b*) Honorary Corresponding Members, foreign representatives, and other persons specially invited or nominated by the Council or General Officers.
(*c*) Delegates nominated by the Affiliated Societies.
(*d*) Delegates—not exceeding altogether three in number—from Scientific Institutions established at the place of meeting.

Admission. 2. The decision of the Council on the qualifications and claims of any Member of the Association to be placed on the General Committee shall be final.

(i) Claims for admission as a Permanent Member must be lodged with the Assistant Secretary at least one month before the Annual Meeting.
(ii) Claims for admission as a Temporary Member may be sent to the Assistant Secretary at any time before or during the Annual Meeting.

Meetings. 3. The General Committee shall meet twice at least during every Annual Meeting. In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee.

Functions. 4. The General Committee shall

(i) Receive and consider the Report of the Council.
(ii) Elect a Committee of Recommendations.
(iii) Receive and consider the Report of the Committee of Recommendations.
(iv) Determine the place of the Annual Meeting not less than two years in advance.
(v) Determine the date of the next Annual Meeting.
(vi) Elect the President and Vice-Presidents, Local Treasurer, and Local Secretaries for the next Annual Meeting.
(vii) Elect Ordinary Members of Council.
(viii) Appoint General Officers.
(ix) Appoint Auditors.
(x) Elect the Officers of the Conference of Delegates.
(xi) Receive any notice of motion for the next Annual Meeting.

Chapter III.

Committee of Recommendations.

Constitution.

1. * The *ex officio* Members of the Committee of Recommendations are the President and Vice-Presidents of the Association, the President of each Section at the Annual Meeting, the Chairman of the Conference of Delegates, the General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years.

An Ordinary Member of the Committee for each Section shall be nominated by the Committee of that Section.

If the President of a Section be unable to attend a meeting of the Committee of Recommendations, the Sectional Committee may appoint a Vice-President, or some other member of the Committee, to attend in his place, due notice of such appointment being sent to the Assistant Secretary.

Functions.

2. Every recommendation made under Chapter IV. and every resolution on a scientific subject, which may be submitted to the Association by any Sectional Committee, or by the Conference of Delegates, or otherwise than by the Council of the Association, shall be submitted to the Committee of Recommendations. If the Committee of Recommendations approve such recommendation, they shall transmit it to the General Committee; and no recommendation shall be considered by the General Committee that is not so transmitted.

Every recommendation adopted by the General Committee shall, if it involve action on the part of the Association, be transmitted to the Council; and the Council shall take such action as may be needful to give effect to it, and shall report to the General Committee not later than the next Annual Meeting.

Every proposal for establishing a new Section or Sub-Section, for altering the title of a Section, or for any other change in the constitutional forms or fundamental rules of the Association, shall be referred to the Committee of Recommendations for their consideration and report.

Procedure.

3. The Committee of Recommendations shall assemble, for the despatch of business, on the Monday of the Annual Meeting, and, if necessary, on the following day. Their Report must be submitted to the General Committee on the last day of the Annual Meeting.

* Amended by the General Committee at Winnipeg, 1909.

CHAPTER IV.

Research Committees.

Procedure. 1. Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section; and, if such proposal be approved, it shall be referred to the Committee of Recommendations.

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee, composed of Members of the Association, to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association; and the Committee of Recommendations may include such recommendation in their report to the General Committee.

Constitution. 2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and suitable Members to serve on it, which must be as small as is consistent with its efficient working; and shall nominate a Chairman and a Secretary. Such Research Committee, if appointed, shall have power to add to their numbers.

Proposals by Sectional Committees. 3. The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required.

All proposals sanctioned by a Sectional Committee shall be forwarded by the Recorder to the Assistant Secretary not later than noon on the Monday of the Annual Meeting for presentation to the Committee of Recommendations.

Tenure. 4. Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment, with or without a grant—or a further grant—of money.

Reports. 5. Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed. Interim Reports, whether intended for publication or not, must be submitted in writing. Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee appointed on their recommendation, and shall report to the Committee of Recommendations on or before the Monday of the Annual Meeting.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for such portion of the sum granted as from time to time may be required. **GRANTS. (a) Drawn by Chairman.**

Grants of money sanctioned at the Annual Meeting expire on June 30 following. The General Treasurer is not authorised, after that date, to allow any claims on account of such grants. **(b) Expire on June 30.**

The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then return the balance of the grant, if any, which remains unexpended; provided that a Research Committee may, in the first year of its appointment only, apply for leave to retain an unexpended balance when or before its Report is presented, due reason being given for such application.* **(c) Accounts and balance in hand**

When application is made for a Committee to be reappointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired. (d) Additional Grant.

In making grants of money to Research Committees, the Association does not contemplate the payment of personal expenses to the Members. (e) *Caveat.*

A Research Committee, whether or not in receipt of a grant, shall not raise money, in the name or under the auspices of the Association, without special permission from the General Committee.

7. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their Reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct. Disposal of specimens, apparatus, &c.

Committees are required to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

* Amended by the General Committee at Dundee, 1912.

Chapter V.

The Council.

Constitution. 1. The Council shall consist of *ex officio* Members and of Ordinary Members elected annually by the General Committee.

(i) The *ex officio* Members are—the Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

(ii) The Ordinary Members shall not exceed twenty-five in number. Of these, not more than twenty shall have served on the Council as Ordinary Members in the previous year.

Functions. 2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee.

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt the Annual Report, and to consider other matters to be brought before the General Committee.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

Suggestions for the Presidency shall be considered by the Council at the Meeting in February, and the names selected shall be issued with the summonses to the Council Meeting in March, when the nomination shall be made from the names on the list.

The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as they may from time to time determine.

3. Election to the Council shall take place at the same time as that of the Officers of the Association. **Elections.**

(i) At each Annual Election, the following Ordinary Members of the Council shall be ineligible for re-election in the ensuing year:

(*a*) Three of the Members who have served for the longest consecutive period, and

(*b*) Two of the Members who, being resident in or near London, have attended the least number of meetings during the past year.

Nevertheless, it shall be competent for the Council, by an unanimous vote, to reverse the proportion in the order of retirement above set forth.

(ii) The Council shall submit to the General Committee, in their Annual Report, the names of twenty-three Members of the Association whom they recommend for election as Members of Council.

(iii) Two Members shall be elected by the General Committee, without nomination by the Council; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place.

Any member of the General Committee may propose another member thereof for election as one of these two Members of Council, and, if only two are so proposed, they shall be declared elected; but, if more than two are so proposed, the election shall be by show of hands, unless five Members at least require it to be by ballot.

CHAPTER VI.

The President, General Officers, and Staff

1. The President assumes office on the first day of the Annual Meeting, when he delivers a Presidential Address. He resigns office at the next Annual Meeting, when he inducts his successor into the Chair. **The President.**

The President shall preside at all meetings of the Association or of its Council and Committees which he attends in his capacity as President. In his absence, he shall be represented by a Vice-President or past President of the Association.

2. The General Officers of the Association are the General Treasurer and the General Secretaries. **General Officers.**

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

The General Treasurer.

3. The General Treasurer shall be responsible to the General Committee and the Council for the financial affairs of the Association.

The General Secretaries.

4. The General Secretaries shall control the general organisation and administration, and shall be responsible to the General Committee and the Council for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance.

The Assistant Secretary.

5. The Assistant Secretary shall hold office during the pleasure of the Council. He shall act under the direction of the General Secretaries, and in their absence shall represent them. He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relates to the finances of the Association.

The Assistant Secretary shall be charged, subject as aforesaid: (i) with the general organising and editorial work, and with the administrative business of the Association; (ii) with the control and direction of the Office and of all persons therein employed; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council. He shall act as Secretary, and take Minutes, at the meetings of the Council, and at all meetings of Committees of the Council, of the Committee of Recommendations, and of the General Committee.

Assistant Treasurer.

6. The General Treasurer may depute one of the Staff, as Assistant Treasurer, to carry on, under his direction, the routine work of the duties of his office.

The Assistant Treasurer shall be charged with the issue of Membership Tickets, the payment of Grants, and such other work as may be delegated to him.

Chapter VII.

Finance.

Financial Statements.

1. The General Treasurer, or Assistant Treasurer, shall receive and acknowledge all sums of money paid to the Association. He shall submit, at each meeting of the Council, an interim statement of his Account; and, after

June 30 in each year, he shall prepare and submit to the General Committee a balance-sheet of the Funds of the Association.

2. The Accounts of the Association shall be audited, annually, by Auditors appointed by the General Committee. Audit.

3. The General Treasurer shall make all ordinary payments authorised by the General Committee or by the Council. Expenditure.

4. The General Treasurer is empowered to draw on the account of the Association, and to invest on its behalf, part or all of the balance standing at any time to the credit of the Association in the books of the Bank of England, either in Exchequer Bills or in any other temporary investment, and to change, sell, or otherwise deal with such temporary investment as may seem to him desirable. Investments.

5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association. Cheques.

CHAPTER VIII.

The Annual Meetings.

1. Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number. Local Officers and Committees

2. The General Committee shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Assistant Secretary as to the local arrangements necessary for the conduct of the meeting. The Local Treasurers shall be empowered to enrol Members and Associates, and to receive subscriptions.

3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections. Functions.

Chapter IX.

The Work of the Sections.

The Sections. 1. The scientific work of the Association shall be transacted under such Sections as shall be constituted from time to time by the General Committee.

It shall be competent for any Section, if authorised by the Council for the time being, to form a Sub-Section for the purpose of dealing separately with any group of communications addressed to that Section.

Sectional Officers. 2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries. They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

Rooms. 3. The Section Rooms and the approaches thereto shall not be used for any notices, exhibitions, or other purposes than those of the Association.

Sectional Committees. 4. The work of each Section shall be conducted by a Sectional Committee, which shall consist of the following :—

Constitution.

(i) The Officers of the Section during their term of office.
(ii) All past Presidents of that Section.
(iii) Such other Members of the Association, present at any Annual Meeting, as the Sectional Committee, thus constituted, may co-opt for the period of the meeting :

Provided always that—

Privilege of Old Members. (*a*) Any Member of the Association who has served on the Committee of any Section in any previous year, and who has intimated his intention of being present at the Annual Meeting, is eligible as a member of that Committee at their first meeting.

Daily Co-optation. (*b*) A Sectional Committee may co-opt members, as above set forth, at any time during the Annual Meeting, and shall publish daily a revised list of the members.

(c) A Sectional Committee may, at any time during the Annual Meeting, appoint not more than three persons present at the meeting to be Vice-Presidents of the Section, in addition to those previously appointed by the Council. Additional Vice-Presidents.

5. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee; and they shall report such action to the Sectional Committee at its next meeting. EXECUTIVE FUNCTIONS

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise. Of President

The Recorder shall be responsible for the punctual transmission to the Assistant Secretary of the daily programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee. and of Recorder.

6. The Sectional Committee shall nominate, before the close of the Annual Meeting, not more than six of its own members to be members of an Organising Committee, with the officers to be subsequently appointed by the Council, and past Presidents of the Section, from the close of the Annual Meeting until the conclusion of its meeting on the first day of the ensuing Annual Meeting. Organising Committee.

Each Organising Committee shall hold such meetings as are deemed necessary by its President for the organisation of the ensuing Sectional proceedings, and shall hold a meeting on the first Wednesday of the Annual Meeting: to nominate members of the Sectional Committee, to confirm the Provisional Programme of the Section, and to report to the Sectional Committee.

Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting: to co-opt members, to complete the arrangements for the next day, and to take into consideration any suggestion for the advancement of Science that may be offered by a member, or may arise out of the proceedings of the Section. Sectional Committee.

No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes. Papers and Reports.

Any report or paper read in any one Section may be read also in any other Section.

No paper or abstract of a paper shall be printed in the Annual Report of the Association unless the manuscript has been received by the Recorder of the Section before the close of the Annual Meeting.

Recommendations.

It shall be within the competence of the Sectional Committee to review the recommendations adopted at preceding Annual Meetings, as published in the Annual Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed; and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required: to make recommendations and nominate individuals or Research Committees to whom the preparation of such reports, or the task of research, may be entrusted, discriminating as to whether, and in what respects, these objects may be usefully advanced by the appropriation of money from the funds of the Association, whether by reference to local authorities, public institutions, or Departments of His Majesty's Government. The appointment of such Research Committees shall be made in accordance with the provisions of Chapter IV.

No proposal arising out of the proceedings of any Section shall be referred to the Committee of Recommendations unless it shall have received the sanction of the Sectional Committee.

Publication.

7. Papers ordered to be printed *in extenso* shall not be included in the Annual Report, if published elsewhere prior to the issue of the Annual Report in volume form. Reports of Research Committees shall not be published elsewhere than in the Annual Report without the express sanction of the Council.

Copyright.

8. The copyright of papers ordered by the General Committee to be printed *in extenso* in the Annual Report shall be vested in the authors; and the copyright of the reports of Research Committees appointed by the General Committee shall be vested in the Association.

CHAPTER X.

Admission of Members and Associates.

1. No technical qualification shall be required on the part of an applicant for admission as a Member or as an Associate of the British Association; but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect. **Applications.**

* Every person admitted as a Member or an Associate shall conform to the Rules and Regulations of the Association, any infringement of which on his part may render him liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued. **Obligations.**

It shall be competent for the General Officers to act, in the name of the Council, on any occasion of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next Meeting.

2. All Members are eligible to any office in the Association. **Conditions and Privileges of Membership.**

(i) Every *Life Member* shall pay, on admission, the sum of Ten Pounds.

Life Members shall receive *gratis* the Annual Reports of the Association.

(ii) Every *Annual Member* shall pay, on admission, the sum of Two Pounds, and in any subsequent year the sum of One Pound.

Annual Members shall receive *gratis* the Report of the Association for the year of their admission and for the years in which they continue to pay, *without intermission*, their annual subscription. An Annual Member who omits to subscribe for any particular year shall lose for that and all future years the privilege of receiving the Annual Reports of the Association *gratis*. He, however, may resume his other privileges as a Member at any subsequent Annual Meeting by paying on each such occasion the sum of One Pound.

(iii) Every *Associate* for a year shall pay, on admission, the sum of One Pound.

* Amended by the General Committee at Dublin, 1908.

Associates shall not receive the Annual Report gratuitously. They shall not be eligible to serve on any Committee, nor be qualified to hold any office in the Association.

(iv) *Ladies* may become Members or Associates on the same terms as gentlemen, or can obtain a *Lady's Ticket* (transferable to ladies only) on the payment of One Pound.

Corresponding Members. 3. Corresponding Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership.

Annual Subscriptions. 4. Subscriptions are payable at or before the Annual Meeting. Annual Members not attending the meeting may make payment at any time before the close of the financial year on June 30 of the following year.

The Annual Report. 5. The Annual Report of the Association shall be forwarded *gratis* to individuals and institutions entitled to receive it.

Annual Members whose subscriptions have been intermitted shall be entitled to purchase the Annual Report at two-thirds of the publication price; and Associates for a year shall be entitled to purchase, at the same price, the volume for that year.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Chapter XI.

Corresponding Societies: Conference of Delegates.

Corresponding Societies are constituted as follows:

AFFILIATED SOCIETIES. 1. (i) Any Society which undertakes local scientific investigation and publishes the results may become a Society *affiliated* to the British Association.

Each Affiliated Society may appoint a Delegate, who must be or become a Member of the Association and must attend the meetings of the Conference of Delegates. He shall be *ex officio* a Member of the General Committee.

ASSOCIATED SOCIETIES. (ii) Any Society formed for the purpose of encouraging the study of Science, which has existed for three years and numbers not fewer than fifty members, may become a Society *associated* with the British Association.

Each Associated Society shall have the right to appoint a Delegate to attend the Annual Conference. Such Delegates must be or become either Members or Associates of the British Association, and shall have all the rights of Delegates appointed by the Affiliated Societies, except that of membership of the General Committee.

2. Application may be made by any Society to be placed on the list of Corresponding Societies. Such application must be addressed to the Assistant Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended it should be considered, and must, in the case of Societies desiring to be affiliated, be accompanied by specimens of the publications of the results of local scientific investigations recently undertaken by the Society. **Applications.**

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee, for the purpose of keeping themselves generally informed of the work of the Corresponding Societies and of superintending the preparation of a list of the papers published by the Affiliated Societies. This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable. CORRESPONDING SOCIETIES COMMITTEE.

(i) Each Corresponding Society shall forward every year to the Assistant Secretary of the Association, on or before June 1, such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee. Procedure.

(ii) There shall be inserted in the Annual Report of the Association a list of the papers published by the Corresponding Societies during the preceding twelve months which contain the results of local scientific work conducted by them—those papers only being included which refer to subjects coming under the cognisance of one or other of the several Sections of the Association.

4. The Delegates of Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairman, and Secretary or Secretaries shall be nominated annually by the Council and appointed by the General Committee. The members of the Corresponding Societies Committee shall be *ex officio* members of the Conference. CONFERENCE OF DELEGATES.

(i) The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during **Procedure and Functions.**

each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the discussions.

(ii) The Conference of Delegates shall be empowered to submit Resolutions to the Committee of Recommendations for their consideration, and for report to the General Committee.

(iii) The Sectional Committees of the Association shall be requested to transmit to the Secretaries of the Conference of Delegates copies of any recommendations to be made to the General Committee bearing on matters in which the co-operation of Corresponding Societies is desirable. It shall be competent for the Secretaries of the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect.

(iv) It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they may be able to bring such recommendations adequately before their respective Societies.

(v) The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results.

Chapter XII.

Amendments and New Rules.

Alterations. Any alterations in the Rules, and any amendments or new Rules that may be proposed by the Council or individual Members, shall be notified to the General Committee on the first day of the Annual Meeting, and referred forthwith to the Committee of Recommendations; and, on the report of that Committee, shall be submitted for approval at the last meeting of the General Committee.

TRUSTEES, GENERAL OFFICERS, &c., 1831–1914.

TRUSTEES.

1832–70 (Sir) R. I. MURCHISON (Bart.), F.R.S.
1832–62 JOHN TAYLOR, Esq., F.R.S.
1832–39 C. BABBAGE, Esq., F.R.S.
1839–44 F. BAILY, Esq., F.R.S.
1844–58 Rev. G. PEACOCK, F.R.S.
1858–82 General E. SABINE, F.R.S.
1862–81 Sir P. EGERTON, Bart., F.R.S.
1872–1913 Sir J. LUBBOCK, Bart. (afterwards Lord AVEBURY), F.R.S.
1881–83 W. SPOTTISWOODE, Esq., Pres. R.S.
1883– Lord RAYLEIGH, F.R.S.
1883–98 Sir LYON (afterwards Lord) PLAYFAIR, F.R.S.
1898– Prof. (Sir) A. W. RÜCKER, F.R.S.
1913– Major P. A. MACMAHON, F.R.S.

GENERAL TREASURERS.

1831 JONATHAN GRAY, Esq.
1832–62 JOHN TAYLOR, Esq., F.R.S.
1862–74 W. SPOTTISWOODE, Esq., F.R.S.
1874–91 Prof. A. W. WILLIAMSON, F.R.S.
1891–98 Prof. (Sir) A. W. RÜCKER, F.R.S.
1898–1904 Prof. G. C. FOSTER, F.R.S.
1904– Prof. JOHN PERRY, F.R.S.

GENERAL SECRETARIES.

1832–35 Rev. W. VERNON HARCOURT, F.R.S.
1835–36 Rev. W. VERNON HARCOURT, F.R.S., and F. BAILY, Esq., F.R.S.
1836–37 Rev. W. VERNON HARCOURT, F.R.S., and R. I. MURCHISON, Esq., F.R.S.
1837–39 R. I. MURCHISON, Esq., F.R.S., and Rev. G. PEACOCK, F.R.S.
1839–45 Sir R. I. MURCHISON, F.R.S., and Major E. SABINE, F.R.S.
1845–50 Lieut.-Colonel E. SABINE, F.R.S.
1850–52 General E. SABINE, F.R.S., and J. F. ROYLE, Esq., F.R.S.
1852–53 J. F. ROYLE, Esq., F.R.S.
1853–59 General E. SABINE, F.R.S.
1859–61 Prof. R. WALKER, F.R.S.
1861–62 W. HOPKINS, Esq., F.R.S.
1862–63 W. HOPKINS, Esq., F.R.S., and Prof. J. PHILLIPS, F.R.S.
1863–65 W. HOPKINS, Esq., F.R.S., and F. GALTON, Esq., F.R.S.
1865–66 F. GALTON, Esq., F.R.S.
1866–68 F. GALTON, Esq., F.R.S., and Dr. T. A. HIRST, F.R.S.
1868–71 Dr. T. A. HIRST, F.R.S., and Dr. T. THOMSON, F.R.S.
1871–72 Dr. T. THOMSON, F.R.S., and Capt. DOUGLAS GALTON, F.R.S.
1872–76 Capt. D. GALTON, F.R.S., and Dr. MICHAEL FOSTER, F.R.S.
1876–81 Capt. D. GALTON, F.R.S., and Dr. P. L. SCLATER, F.R.S.
1881–82 Capt. D. GALTON, F.R.S., and Prof. F. M. BALFOUR, F.R.S.
1882–83 Capt. DOUGLAS GALTON, F.R.S.
1883–95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895–97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHÄFER, F.R.S.
1897–1900 Prof. SCHÄFER, F.R.S., and Sir W. C. ROBERTS-AUSTEN, F.R.S.
1900–02 Sir W. C. ROBERTS-AUSTEN, F.R.S., and Dr. D. H. SCOTT, F.R.S.
1902–03 Dr. D. H. SCOTT, F.R.S., and Major P. A. MACMAHON, F.R.S.
1903–13 Major P. A. MACMAHON, F.R.S., and Prof. W. A. HERDMAN, F.R.S.
1913– Prof. W. A. HERDMAN, F.R.S., and Prof. H. H. TURNER, F.R.S.

ASSISTANT GENERAL SECRETARIES, &c.: 1831–1904.

1831 JOHN PHILLIPS, Esq., *Secretary.*
1832 Prof. J. D. FORBES, *Acting Secretary.*
1832–62 Prof. JOHN PHILLIPS, F.R.S.
1862–78 G. GRIFFITH, Esq., M.A.
1881 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1881–85 Prof. T. G. BONNEY, F.R.S., *Secretary.*
1885–90 A. T. ATCHISON, Esq., M.A., *Secretary.*
1890 G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1890–1902 G. GRIFFITH, Esq., M.A.
1902–04 J. G. GARSON, Esq., M.D.

ASSISTANT SECRETARIES.

1878–80 J. E. H. GORDON, Esq., B.A.
1904–09 A. SILVA WHITE, Esq.
1909– O. J. R. HOWARTH, Esq., M.A.

Presidents and Secretaries of the Sections of the Association, 1901–1913.

(The List of Sectional Officers for 1914 will be found on p. xlvi.)

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)

SECTION A.[1]—MATHEMATICS AND PHYSICS.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1901. Glasgow ...	Major P. A. MacMahon, F.R.S. —*Dep. of Astronomy*, Prof. H. H. Turner, F.R.S.	H. S. Carslaw, C. H. Lees (*Rec.*), W. Stewart, Prof. L. R. Wilberforce.
1902. Belfast......	Prof. J. Purser, LL.D., M.R.I.A. —*Dep. of Astronomy*, Prof. A. Schuster, F.R.S.	H. S. Carslaw, A. R. Hinks, A. Larmor, C. H. Lees (*Rec.*), Prof. W. B. Morton, A. W. Porter.
1903. Southport	C. Vernon Boys, F.R.S.—*Dep. of Astronomy and Meteorology*, Dr. W. N. Shaw, F.R.S.	D. E. Benson, A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees (*Rec.*), J. Loton, A. W. Porter.
1904. Cambridge	Prof. H. Lamb, F.R.S.—*Sub-Section of Astronomy and Cosmical Physics*, Sir J. Eliot, K.C.I.E., F.R.S.	A. R. Hinks, R. W. H. T. Hudson, Dr. C. H. Lees (*Rec.*), Dr. W. J. S. Lockyer, A. W. Porter, W. C. D. Whetham.
1905. South Africa	Prof. A. R. Forsyth, M.A., F.R.S.	A. R. Hinks, S. S. Hough, R. T. A. Innes, J. H. Jeans, Dr. C. H. Lees (*Rec.*).
1906. York.........	Principal E. H. Griffiths, F.R.S.	Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter (*Rec.*), H. Dennis Taylor.
1907. Leicester...	Prof. A. E. H. Love, M.A., F.R.S.	E. E. Brooks, Dr. L. N. G. Filon, Dr. J. A. Harker, A. R. Hinks, Prof. A. W. Porter (*Rec.*).
1908. Dublin	Dr. W. N. Shaw, F.R.S.	Dr. W. G. Duffield, Dr. L. N. G. Filon, E. Gold, Prof. J. A. McClelland, Prof. A. W. Porter (*Rec.*), Prof. E. T. Whittaker.
1909. Winnipeg	Prof. E. Rutherford, F.R.S....	Prof. F. Allen, Prof. J. C. Fields, E. Gold, F. Horton, Prof. A. W. Porter (*Rec.*), Dr. A. A. Rambaut.
1910. Sheffield ...	Prof. E. W. Hobson, F.R.S....	H. Bateman, A. S. Eddington, E. Gold, Dr. F. Horton, Dr. S. R. Milner, Prof. A. W. Porter (*Rec.*).
1911. Portsmouth	Prof. H. H. Turner, F.R.S. ...	H. Bateman, Prof. P. V. Bevan, A. S. Eddington, E. Gold, Prof. A. W. Porter (*Rec.*), P. A. Yapp.
1912. Dundee ...	Prof. H. L. Callendar, F.R.S.	Prof. P. V. Bevan, E. Gold, Dr. H. B. Heywood, R. Norrie, Prof. A. W. Porter (*Rec.*), W. G. Robson, F. J. M. Stratton.
1913. Birmingham	Dr. H. F. Baker, F.R.S.	Prof. P. V. Bevan (*Rec.*), Prof. A. S. Eddington, E. Gold, Dr. H. B. Heywood, Dr. A. O. Rankine, Dr. G. A. Shakespear.

[1] Section A was constituted under this title in 1835, when the sectional division was introduced. The previous division was into 'Committees of Sciences.'

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)

SECTION B.[2]—CHEMISTRY.

1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose (*Rec.*).
1902. Belfast......	Prof. E. Divers, F.R.S..........	R. F. Blake, M. O. Forster, Prof. G. G. Henderson, Prof. W. J. Pope (*Rec.*).
1903. Southport	Prof. W. N. Hartley, D.Sc., F.R.S.	Dr. M. O. Forster, Prof. G. G. Henderson, J. Ohm, Prof. W. J. Pope (*Rec.*).
1904. Cambridge	Prof. Sydney Young, F.R.S....	Dr. M. O. Forster, Prof. G. G. Henderson, Dr. H. O. Jones, Prof. W. J. Pope (*Rec.*).
1905. South Africa	George T. Beilby	W. A. Caldecott, Mr. M. O. Forster, Prof. G. G. Henderson (*Rec.*), C. F. Juritz.
1906. York.........	Prof. Wyndham R. Dunstan, F.R.S.	Dr. E. F. Armstrong, Prof. A. W. Crossley, S. H. Davies, Prof. W. J. Pope (*Rec.*).
1907. Leicester ...	Prof. A. Smithells, F.R.S.	Dr. E. F. Armstrong, Prof. A. W. Crossley (*Rec.*), J. H. Hawthorn, Dr. F. M. Perkin.
1908. Dublin	Prof. F. S. Kipping, F.R.S. ...	Dr. E. F. Armstrong (*Rec.*), Dr. A. McKenzie, Dr. F. M. Perkin, Dr. J. H. Pollock.
1909. Winnipeg...	Prof. H. E. Armstrong, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. T. M. Lowry, Dr. F. M. Perkin, J. W. Shipley.
1910. Sheffield ...	J. E. Stead, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. T. M. Lowry, Dr. F. M. Perkin, W. E. S. Turner.
	Sub-section of Agriculture—A. D. Hall, F.R.S.	Dr. C. Crowther, J. Golding, Dr. E. J. Russell.
1911. Portsmouth	Prof. J. Walker, F.R.S.	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. T. M. Lowry, Dr. F. Beddow.
1912. Dundee ...	Prof. A. Senier, M.D.	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. A. Holt, Dr. J. K. Wood.
1913. Birmingham	Prof. W. P. Wynne, F.R.S. ...	Dr. E. F. Armstrong (*Rec.*), Dr. C. H. Desch, Dr. A. Holt, Dr. H. McCombie.

SECTION C.[3]—GEOLOGY.

1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton (*Rec.*).
1902. Belfast......	Lieut.-Gen. C. A. McMahon, F.R.S.	H. L. Bowman, H. W. Monckton (*Rec.*), J. St. J. Phillips, H. J. Seymour.
1903. Southport	Prof. W. W. Watts, M.A., M.Sc.	H. L. Bowman, Rev. W. L. Carter, J. Lomas, H. W. Monckton (*Rec.*).

[2] 'Chemistry and Mineralogy,' 1835-1894.
[3] 'Geology and Geography,' 1835-1850.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1904. Cambridge	Aubrey Strahan, F.R.S.	H. L. Bowman (*Rec.*), Rev. W. L. Carter, J. Lomas, H. Woods.
1905. SouthAfrica	Prof. H. A. Miers, M.A., D.Sc., F.R.S.	H. L. Bowman (*Rec.*), J. Lomas, Dr. Molengraaff, Prof. A. Young, Prof. R. B. Young.
1906. York.........	G. W. Lamplugh, F.R.S.	H. L. Bowman (*Rec.*), Rev. W. L. Carter, Rev. W. Johnson, J. Lomas.
1907. Leicester...	Prof. J. W. Gregory, F.R.S....	Dr. F. W. Bennett, Rev. W. L. Carter, Prof. T. Groom, J. Lomas (*Rec.*)
1908. Dublin......	Prof. John Joly, F.R.S.	Rev. W. L. Carter, J. Lomas (*Rec.*), Prof. S. H. Reynolds, H. J. Seymour.
1909. Winnipeg...	Dr. A. Smith Woodward, F.R.S.	W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, R. T. Hodgson, Prof. S. H. Reynolds.
1910. Sheffield ...	Prof. A. P. Coleman, F.R.S...	W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, B. Hobson, Prof. S. H. Reynolds.
1911. Portsmouth	A. Harker, F.R.S.	Col. C. W. Bevis, W. L. Carter (*Rec.*), Dr. A. R. Dwerryhouse, Prof. S. H. Reynolds.
1912. Dundee ...	Dr. B. N. Peach, F.R.S.	Prof. W. B. Boulton, A. W. R. Don, Dr. A. R. Dwerryhouse (*Rec.*), Prof. S. H. Reynolds.
1913 Birmingham	Prof. E. J. Garwood, M.A. ...	Prof. W. S. Boulton, Dr. A. R. Dwerryhouse (*Rec.*), F. Raw, Prof. S. H. Reynolds.

SECTION D.[4]—ZOOLOGY.

1901. Glasgow ...	Prof. J. Cossar Ewart, F.R.S.	J. G. Kerr (*Rec.*), J. Rankin, J. Y. Simpson.
1902. Belfast......	Prof. G. B. Howes, F.R.S. ...	Prof. J. G. Kerr, R. Patterson, J. Y. Simpson (*Rec.*).
1903. Southport	Prof. S. J. Hickson, F.R.S. ...	Dr. J. H. Ashworth, J. Barcroft, A. Quayle, Dr. J. Y. Simpson (*Rec.*), Dr. H. W. M. Tims.
1904. Cambridge	William Bateson, F.R.S.......	Dr. J. H. Ashworth, L. Doncaster, Prof. J. Y. Simpson (*Rec.*), Dr. H. W. M. Tims.
1905. SouthAfrica	G. A. Boulenger, F.R.S.	Dr. Pakes, Dr. Purcell, Dr. H. W. M. Tims, Prof. J. Y. Simpson (*Rec.*).
1906. York.........	J. J. Lister, F.R.S.	Dr. J. H. Ashworth, L. Doncaster, Oxley Grabham, Dr. H. W. M. Tims (*Rec.*).
1907. Leicester...	Dr. W. E. Hoyle, M.A..........	Dr. J. H. Ashworth, L. Doncaster, E. E. Lowe, Dr. H. W. M. Tims (*Rec.*).
1908. Dublin......	Dr. S. F. Harmer, F.R.S.......	Dr. J. H. Ashworth, L. Doncaster, Prof. A. Fraser, Dr. H. W. M. Tims (*Rec.*).
1909. Winnipeg...	Dr. A. E. Shipley, F.R.S. ...	C. A. Baragar, C. L. Boulenger, Dr. J. Pearson, Dr. H. W. M. Tims (*Rec.*).

[4] 'Zoology and Botany,' 1835-1847; 'Zoology and Botany, including Physiology,' 1848-1865; 'Biology,' 1866-1894.

Date and Place	Presidents	Secretaries (*Rec.*=Recorder)
1910. Sheffield ...	Prof. G. C. Bourne, F.R.S. ...	Dr. J. H. Ashworth, L. Doncaster, T. J. Evans, Dr. H. W. M. Tims (*Rec.*).
1911. Portsmouth	Prof. D'Arcy W. Thompson, C.B.	Dr. J. H. Ashworth, C. Foran, R. D. Laurie, Dr. H. W. M. Tims (*Rec.*).
1912. Dundee ...	Dr. P. Chalmers Mitchell, F.R.S.	Dr. J. H. Ashworth, R. D. Laurie, Miss D. L. Mackinnon, Dr H. W. M. Tims (*Rec.*).
1913. Birmingham	Dr. H. F. Gadow, F.R.S.......	Dr. J. H. Ashworth, Dr. C. L. Boulenger, R. D. Laurie, Dr. H. W. M. Tims (*Rec.*).

SECTION E.[5]—GEOGRAPHY.

1901. Glasgow ...	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson (*Rec.*), E. Heawood, G. Sandeman, A. C. Turner.
1902. Belfast......	Sir T. H. Holdich, K.C.B. ...	G. G. Chisholm (*Rec.*), E. Heawood, Dr. A. J. Herbertson, Dr. J. A. Lindsay.
1903. Southport...	Capt. E. W. Creak, R.N., C.B., F.R.S.	E. Heawood (*Rec.*), Dr. A. J. Herbertson, E. A. Reeves, Capt. J. C. Underwood.
1904. Cambridge	Douglas W. Freshfield.........	E. Heawood (*Rec.*), Dr. A. J. Herbertson, H. Y. Oldham, E. A. Reeves.
1905. South Africa	Adm. Sir W. J. L. Wharton, R.N., K.C.B., F.R.S.	A. H. Cornish-Bowden, F. Flowers, Dr. A. J. Herbertson (*Rec.*), H. Y. Oldham.
1906. York.	Rt. Hon. Sir George Goldie, K.C.M.G., F.R.S.	E. Heawood (*Rec.*), Dr. A. J. Herbertson, E. A. Reeves, G. Yeld.
1907. Leicester...	George G. Chisholm, M.A. ...	E. Heawood (*Rec.*), O. J. R. Howarth, E. A. Reeves, T. Walker.
1908. Dublin	Major E. H. Hills, C.M.G., R.E.	W. F. Bailey, W. J. Barton, O. J. R. Howarth (*Rec.*), E. A. Reeves.
1909. Winnipeg...	Col. Sir D. Johnston, K.C.M.G., C.B., R.E.	G. G. Chisholm (*Rec.*), J. McFarlane, A. McIntyre.
1910. Sheffield ...	Prof. A. J. Herbertson, M.A., Ph.D.	Rev. W. J. Barton (*Rec.*), Dr. R. Brown, J. McFarlane, E. A. Reeves.
1911. Portsmouth	Col. C. F. Close, R.E., C.M.G.	J. McFarlane (*Rec.*), E. A. Reeves, W. P. Smith.
1912. Dundee ..	Col. Sir C. M. Watson, K.C.M.G.	Rev. W. J. Barton (*Rec.*), J. McFarlane, E. A. Reeves, D. Wylie.
1913. Birmingham	Prof. H. N. Dickson, D.Sc. ...	Rev. W. J. Barton (*Rec.*), P. E. Martineau, J. McFarlane, E. A. Reeves.

SECTION F.[6]—ECONOMIC SCIENCE AND STATISTICS.

1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan (*Rec.*), S. J. Chapman.
1902. Belfast ...	E. Cannan, M.A., LL.D.	A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. A. Duffin.

[5] Section E was that of 'Anatomy and Medicine,' 1835–1840; of 'Physiology' (afterwards incorporated in Section D), 1841–1847. It was assigned to 'Geography and Ethnology,' 1851–1868; 'Geography,' 1869.

[6] 'Statistics,' 1835–1855.

Date and Place	Presidents	Secretaries (Rec. = Recorder)
1903. Southport	E. W. Brabrook, C.B.	A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. B. W. Ginsburg, G. Lloyd.
1904. Cambridge	Prof. Wm. Smart, LL.D.	J. E. Bidwell, A. L. Bowley (*Rec.*), Prof. S. J. Chapman, Dr. B. W. Ginsburg.
1905. SouthAfrica	Rev. W. Cunningham, D.D., D.Sc.	R. à Ababrelton, A. L. Bowley (*Rec.*), Prof. H. E. S. Fremantle, H. O. Meredith.
1906. York.........	A. L. Bowley, M.A.	Prof. S. J. Chapman (*Rec.*), D. H. Macgregor, H. O. Meredith, B. S. Rowntree.
1907. Leicester...	Prof. W. J. Ashley, M.A.......	Prof. S. J. Chapman (*Rec.*), D. H. Macgregor, H. O. Meredith, T. S. Taylor.
1908. Dublin......	W. M. Acworth, M.A.	W. G. S. Adams, Prof. S. J. Chapman (*Rec.*), Prof. D. H. Macgregor, H. O. Meredith.
	Sub-section of Agriculture—Rt. Hon. Sir H. Plunkett.	A. D. Hall, Prof. J. Percival, J. H. Priestley, Prof. J. Wilson.
1909. Winnipeg...	Prof. S. J. Chapman, M.A. ...	Prof. A. B. Clark, Dr. W. A. Manahan, Dr. W. R. Scott (*Rec.*).
1910. Sheffield ...	Sir H. Llewellyn Smith, K.C.B., M.A.	C. R. Fay, H. O. Meredith (*Rec.*), Dr. W. R. Scott, R. Wilson.
1911. Portsmouth	Hon. W. Pember Reeves	C. R. Fay, Dr. W. R. Scott (*Rec.*), H. A. Stibbs.
1912. Dundee ...	Sir H. H. Cunynghame, K.C.B.	C. R. Fay, Dr. W. R. Scott (*Rec.*), E. Tosh.
1913. Birmingham	Rev. P. H. Wicksteed, M.A.	C. R. Fay, Prof. A. W. Kirkaldy, Prof. H. O. Meredith, Dr. W. R. Scott (*Rec.*).

SECTION G.[7]—ENGINEERING.

1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W. E. Dalby, W. A. Price (*Rec.*).
1902. Belfast ...	Prof. J. Perry, F.R.S.	M. Barr, W. A. Price (*Rec.*), J. Wylie.
1903. Southport	C. Hawksley, M.Inst.C.E. ...	Prof. W. E. Dalby, W. T. Maccall, W. A. Price (*Rec.*).
1904. Cambridge	Hon. C. A. Parsons, F.R.S. ...	J. B. Peace, W. T. Maccall, W. A. Price (*Rec.*).
1905. SouthAfrica	Col. Sir C. Scott-Moncrieff, G.C.S.I., K.C.M.G., R.E.	W. T. Maccall, W. B. Marshall (*Rec.*), Prof. H. Payne, E. Williams.
1906. York.........	J. A. Ewing, F.R.S.	W. T. Maccall, W. A. Price (*Rec.*), J. Triffit.
1907. Leicester...	Prof. Silvanus P. Thompson, F.R.S.	Prof. E. G. Coker, A. C. Harris, W. A. Price (*Rec.*), H. E. Wimperis.
1908. Dublin......	Dugald Clerk, F.R.S.	Prof. E. G. Coker, Dr. W. E. Lilly, W. A. Price (*Rec.*), H. E. Wimperis.
1909. Winnipeg...	Sir W. H. White, K.C.B., F.R.S.	E. E. Brydone-Jack, Prof. E. G. Coker, Prof. E. W. Marchant, W. A. Price (*Rec.*).
1910. Sheffield ..	Prof. W. E. Dalby, M.A., M.Inst.C.E.	F. Boulden, Prof. E. G. Coker (*Rec.*), A. A. Rowse, H. E. Wimperis.
1911. Portsmouth	Prof. J. H. Biles, LL.D., D.Sc.	H. Ashley, Prof. E. G. Coker (*Rec.*), A. A. Rowse, H. E. Wimperis.

[7] 'Mechanical Science,' 1836-1900.

Date and Place	Presidents	Secretaries (Rec. = Recorder)
1912. Dundee ...	Prof. A. Barr, D.Sc.	Prof. E. G. Coker (*Rec.*), A. R. Fulton, H. Richardson, A. A. Rowse, H. E. Wimperis.
1913. Birmingham	Prof. Gisbert Kapp, D.Eng....	Prof. E. G. Coker (*Rec.*), J. Purser, A. A. Rowse, H. E. Wimperis.

SECTION H.[8]—ANTHROPOLOGY.

1901. Glasgow ...	Prof. D. J. Cunningham, F.R.S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres (*Rec.*).
1902. Belfast ...	Dr. A. C. Haddon, F.R.S. ...	R. Campbell, Prof. A. F. Dixon J. L. Myres (*Rec.*).
1903. Southport...	Prof. J. Symington, F.R.S....	E. N. Fallaize, H. S. Kingsford, E. M. Littler, J. L. Myres (*Rec.*).
1904. Cambridge	H Balfour, M.A.	W. L. H. Duckworth, E. N. Fallaize, H. S. Kingsford, J. L. Myres (*Rec.*).
1905. SouthAfrica	Dr. A. C. Haddon, F.R.S. ...	A. R. Brown, A. von Dessauer, E. S. Hartland (*Rec.*).
1906. York.........	E. Sidney Hartland, F.S.A....	Dr. G. A. Auden, E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall.
1907. Leicester ..	D. G. Hogarth, M.A............	C. J. Billson, E. N. Fallaize (*Rec.*), H. S. Kingsford, Dr. F. C. Shrubsall.
1908. Dublin	Prof. W. Ridgeway, M.A. ...	E. N. Fallaize (*Rec.*). H. S. Kingsford, Dr. F. C. Shrubsall, L. E. Steele.
1909. Winnipeg...	Prof. J. L. Myres, M.A.	H. S. Kingsford (*Rec.*), Prof. C. J. Patten, Dr. F. C. Shrubsall.
1910. Sheffield ...	W. Crooke, B.A.	E. N. Fallaize (*Rec.*), H. S. Kingsford, Prof. C. J. Patten, Dr. F. C. Shrubsall.
1911. Portsmouth	W. H. R. Rivers, M.D., F.R.S.	E. N. Fallaize (*Rec.*), H. S. Kingsford, E. W. Martindell, H. Rundle. Dr. F. C. Shrubsall.
1912. Dundee. ...	Prof. G. Elliot Smith, F.R.S.	D. D. Craig, E. N. Fallaize (*Rec.*), E. W. Martindell, Dr. F. C. Shrubsall.
1913. Birmingham	Sir Richard Temple, Bart. ...	E. N. Fallaize (*Rec.*), E. W. Martindell, Dr. F. C. Shrubsall, T. Yeates.

SECTION I.[9]—PHYSIOLOGY (including EXPERIMENTAL PATHOLOGY AND EXPERIMENTAL PSYCHOLOGY).

1901. Glasgow ...	Prof. J. G. McKendrick, F.R.S.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson (*Rec.*).
1902. Belfast ...	Prof. W. D. Halliburton, F.R.S.	J. Barcroft, Dr. W. A. Osborne (*Rec.*), Dr. C. Shaw.
1904. Cambridge	Prof. C. S. Sherrington, F.R.S.	J. Barcroft (*Rec.*), Prof. T. G. Brodie, Dr. L. E. Shore.
1905. SouthAfrica	Col. D. Bruce, C.B., F.R.S. ...	J. Barcroft (*Rec.*), Dr. Baumann, Dr. Mackenzie, Dr. G. W. Robertson, Dr. Stanwell.

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[8] Established 1884. [9] Established 1894.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1906. York.........	Prof. F. Gotch, F.R.S.	J. Barcroft (*Rec.*), Dr. J. M. Hamill, Prof. J. S. Macdonald, Dr. D. S. Long.
1907. Leicester...	Dr. A. D. Waller, F.R.S.	Dr. N. H. Alcock, J. Barcroft (*Rec.*), Prof. J. S. Macdonald, Dr. A. Warner.
1908. Dublin......	Dr. J. Scott Haldane, F.R.S.	Prof. D. J. Coffey, Dr. P. T. Herring, Prof. J. S. Macdonald, Dr. H. E. Roaf (*Rec.*).
1909. Winnipeg....	Prof. E. H. Starling, F.R.S....	Dr. N. H. Alcock (*Rec.*), Prof. P. T. Herring, Dr. W. Webster.
1910. Sheffield ...	Prof. A. B. Macallum, F.R.S.	Dr. H. G. M. Henry, Keith Lucas, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1911. Portsmouth	Prof. J. S. Macdonald, B.A.	Dr. J. T. Leon, Dr. Keith Lucas, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1912. Dundee ...	Leonard Hill, F.R.S.	Dr. Keith Lucas, W. Moodie, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.
1913. Birmingham	Dr. F. Gowland Hopkins, F.R.S.	C. L. Burt, Prof. P. T. Herring, Dr. T. G. Maitland, Dr. H. E. Roaf (*Rec.*), Dr. J. Tait.

SECTION K.[10]—BOTANY.

1901. Glasgow ...	Prof. I. B. Balfour, F.R.S. ...	D. T. Gwynne-Vaughan, G. F. Scott-Elliot, A. C. Seward (*Rec.*), H. Wager.
1902. Belfast ...	Prof. J. R. Green, F.R.S.	A. G. Tansley, Rev. C. H. Waddell, H. Wager (*Rec.*), R. H. Yapp.
1903. Southport	A. C. Seward, F.R.S.	H. Ball, A. G. Tansley, H. Wager (*Rec.*), R. H. Yapp.
1904. Cambridge	Francis Darwin, F.R.S. ...... *Sub-section of Agriculture*— Dr. W. Somerville.	Dr. F. F. Blackman, A. G. Tansley, H. Wager (*Rec.*), T. B. Wood, R. H. Yapp.
1905. SouthAfrica	Harold Wager, F.R.S.	R. P. Gregory, Dr. Marloth, Prof. Pearson, Prof. R. H. Yapp (*Rec.*).
1906. York.........	Prof. F. W. Oliver, F.R.S. ...	Dr. A. Burtt, R. P. Gregory, Prof. A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1907. Leicester...	Prof. J. B. Farmer, F.R.S. ...	W. Bell, R. P. Gregory, Prof. A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1908. Dublin......	Dr. F. F. Blackman, F.R.S....	Prof. H. H. Dixon, R. P. Gregory, A. G. Tansley (*Rec.*), Prof. R. H. Yapp.
1909. Winnipeg...	Lieut.-Col. D. Prain, C.I.E., F.R.S.	Prof. A. H. R. Buller, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp (*Rec.*).
	Sub-section of Agriculture— Major P. G. Craigie, C.B.	W. J. Black, Dr. E. J. Russell, Prof. J. Wilson.
1910. Sheffield ...	Prof. J. W. H. Trail, F.R.S	B. H. Bentley, R. P. Gregory, Prof. D. T. Gwynne-Vaughan, Prof. R. H. Yapp (*Rec.*).
1911. Portsmouth	Prof. F. E. Weiss, D.Sc.	C. G. Delahunt, Prof. D. T. Gwynne-Vaughan, Dr. C. E. Moss, Prof. R. H. Yapp (*Rec.*).
	Sub-section of Agriculture— W. Bateson, M.A., F.R.S.	J. Golding, H. R. Pink, Dr. E. J. Russell.

[10] Established 1895.

Date and Place	Presidents	Secretaries (*Rec.* = Recorder)
1912. Dundee ...	Prof. F. Keeble, D.Sc.	J. Brebner, Prof. D. T. Gwynne-Vaughan (*Rec.*), Dr. C. E. Moss, D. Thoday.
1913. Birmingham	Miss Ethel Sargant, F.L.S....	W. B. Grove, Prof. D. T. Gwynne-Vaughan (*Rec.*), Dr. C. E. Moss, D. Thoday.

SECTION L.—EDUCATIONAL SCIENCE.

1901. Glasgow ...	Sir John E. Gorst, F.R.S. ...	R. A. Gregory, W. M. Heller, R. Y. Howie, C. W. Kimmins, Prof. H. L. Withers (*Rec.*).
1902. Belfast ...	Prof. H. E. Armstrong, F.R.S.	Prof. R. A. Gregory, W. M. Heller (*Rec.*), R. M. Jones, Dr. C. W. Kimmins, Prof. H. L. Withers.
1903. Southport ..	Sir W. de W. Abney, K.C.B., F.R.S.	Prof. R. A. Gregory, W. M. Heller (*Rec.*), Dr. C. W. Kimmins, Dr. H. L. Snape.
1904. Cambridge	Bishop of Hereford, D.D. ...	J. H. Flather, Prof. R. A. Gregory, W. M. Heller (*Rec.*), Dr. C. W. Kimmins.
1905. SouthAfrica	Prof. Sir R. C. Jebb, D.C.L., M.P.	A. D. Hall, Prof. Hele-Shaw, Dr. C. W. Kimmins (*Rec.*), J. R. Whitton.
1906. York.........	Prof. M. E. Sadler, LL.D. ...	Prof. R. A. Gregory, W. M. Heller (*Rec.*), Hugh Richardson.
1907. Leicester ...	Sir Philip Magnus, M.P.	W. D. Eggar, Prof. R. A. Gregory (*Rec.*), J. S. Laver, Hugh Richardson.
1908. Dublin	Prof. L. C. Miall, F.R.S.	Prof. E. P. Culverwell, W. D. Eggar, George Fletcher, Prof. R. A. Gregory (*Rec.*), Hugh Richardson.
1909. Winnipeg...	Rev. H. B. Gray, D.D.	W. D. Eggar, R. Fletcher, J. L. Holland (*Rec.*), Hugh Richardson.
1910. Sheffield ...	Principal H. A. Miers, F.R.S.	A. J. Arnold, W. D. Eggar, J. L. Holland (*Rec.*), Hugh Richardson.
1911. Portsmouth	Rt. Rev. J. E. C. Welldon, D.D.	W. D. Eggar, O. Freeman, J. L. Holland (*Rec.*), Hugh Richardson.
1912. Dundee ...	Prof. J. Adams, M.A.	D. Berridge, Dr. J. Davidson, Prof. J. A. Green (*Rec.*), Hugh Richardson.
1913. Birmingham	Principal E. H. Griffiths, F.R.S.	D. Berridge, Rev. S. Blofeld, Prof. J. A. Green (*Rec.*), H. Richardson.

SECTION M.—AGRICULTURE.

1912. Dundee ...	T. H. Middleton, M.A..........	Dr. C. Crowther, J. Golding, Dr. A. Lauder, Dr. E. J. Russell (*Rec.*).
1913. Birmingham	Prof. T. B. Wood, M.A.	W. E. Collinge, Dr. C. Crowther, J. Golding, Dr. E. J. Russell (*Rec.*).

CHAIRMEN AND SECRETARIES OF THE CONFERENCES OF DELEGATES OF CORRESPONDING SOCIETIES, 1901-14.[1]

Date and Place	Chairmen	Secretaries
1901. Glasgow	F. W. Rudler, F.G.S.	Dr. J. G. Garson, A. Somerville.
1902 Belfast	Prof. W. W. Watts, F.G.S.	E. J. Bles.
1903. Southport	W. Whitaker, F.R.S.	F. W. Rudler.
1904. Cambridge	Prof. E. H. Griffiths, F.R.S.	F. W. Rudler.
1905. London	Dr. A. Smith Woodward, F.R.S.	F. W. Rudler.
1906. York	Sir Edward Brabrook, C.B.	F. W. Rudler.
1907. Leicester	H. J. Mackinder, M.A.	F. W. Rudler, I.S.O.
1908. Dublin	Prof. H. A. Miers, F.R.S.	W. P. D. Stebbing.
1909. London	Dr. A. C. Haddon, F.R.S.	W. P. D. Stebbing.
1910. Sheffield	Dr. Tempest Anderson	W. P. D. Stebbing.
1911. Portsmouth	Prof. J. W. Gregory, F.R.S.	W. P. D. Stebbing.
1912. Dundee	Prof. F. O. Bower, F.R.S.	W. P. D. Stebbing.
1913. Birmingham	Dr. P. Chalmers Mitchell, F.R.S.	W. P. D. Stebbing.
1914. Le Havre	Sir H. George Fordham	W. Mark Webb.

EVENING DISCOURSES, 1901-1914.

Date and Place	Lecturer	Subject of Discourse
1901. Glasgow	Prof. W. Ramsay, F.R.S.	The Inert Constituents of the Atmosphere.
	Francis Darwin, F.R.S.	The Movements of Plants.
1902. Belfast	Prof. J. J. Thomson, F.R.S.	Becquerel Rays and Radio-activity.
	Prof. W. F. R. Weldon, F.R.S.	Inheritance.
1903. Southport	Dr. R. Munro	Man as Artist and Sportsman in the Palæolithic Period.
	Dr. A. Rowe	The Old Chalk Sea, and some of its Teachings.
1904. Cambridge	Prof. G. H. Darwin, F.R.S.	Ripple-Marks and Sand-Dunes.
	Prof. H. F. Osborn	Palæontological Discoveries in the Rocky Mountains.
1905. South Africa:		
Cape Town	Prof. E. B. Poulton, F.R.S.	W. J. Burchell's Discoveries in South Africa.
	C. Vernon Boys, F.R.S.	Some Surface Actions of Fluids.
Durban	Douglas W. Freshfield	The Mountains of the Old World.
	Prof. W. A. Herdman, F.R.S.	Marine Biology.
Pietermaritzburg.	Col. D. Bruce, C.B., F.R.S.	Sleeping Sickness.
	H. T. Ferrar	The Cruise of the 'Discovery.'
Johannesburg	Prof. W. E. Ayrton, F.R.S.	The Distribution of Power.
	Prof. J. O. Arnold	Steel as an Igneous Rock.
Pretoria	A. E. Shipley, F.R.S.	Fly-borne Diseases: Malaria, Sleeping Sickness, &c.
Bloemfontein	A. R. Hinks	The Milky Way and the Clouds of Magellan.
Kimberley	Sir Wm. Crookes, F.R.S.	Diamonds.
	Prof. J. B. Porter	The Bearing of Engineering on Mining.
Bulawayo	D. Randall-MacIver	The Ruins of Rhodesia.

[1] Established 1885.

Date and Place	Lecturer	Subject of Discourse
1906. York.........	Dr. Tempest Anderson.........	Volcanoes.
	Dr. A. D. Waller, F.R.S.	The Electrical Signs of Life, and their Abolition by Chloroform.
1907. Leicester...	W. Duddell, F.R.S.	The Ark and the Spark in Radiotelegraphy.
	Dr. F. A. Dixey.................	Recent Developments in the Theory of Mimicry.
1908. Dublin	Prof. H. H. Turner, F.R.S. ...	Halley's Comet.
	Prof. W. M. Davis	The Lessons of the Colorado Canyon.
1909. Winnipeg...	Dr. A. E. H. Tutton, F.R.S....	The Seven Styles of Crystal Architecture.
	Prof. W. A. Herdman, F.R.S.	Our Food from the Waters.
	[1] Prof. H. B. Dixon, F.R.S....	The Chemistry of Flame.
	[1] Prof. J. H. Poynting, F.R.S.	The Pressure of Light.
1910. Sheffield ...	Prof. W. Stirling, M.D.	Types of Animal Movement.[2]
	D. G. Hogarth	New Discoveries about the Hittites.
1911. Portsmouth	Dr. Leonard Hill, F.R.S.......	The Physiology of Submarine Work.
	Prof. A. C. Seward, F.R.S. ...	Links with the Past in the Plant World.
1912. Dundee ...	Prof. W. H. Bragg, F.R.S. ...	Radiations Old and New.
	Prof. A. Keith, M.D............	The Antiquity of Man.
1913. Birmingham	Sir H. H. Cunynghame, K.C.B.	Explosions in Mines and the Means of Preventing them.
	Dr. A. Smith Woodward, F.R.S.	Missing Links among Extinct Animals.
1914. Australia:		
Adelaide	Sir Oliver J. Lodge, F.R.S....	The Ether of Space.
	Prof. W. J. Sollas, F.R.S. ...	Ancient Hunters.
Melbourne	Prof. E. B. Poulton, F.R.S ...	Mimicry.
	Dr. F. W. Dyson, F.R.S. ...	Greenwich Observatory.
Sydney ...	Prof. G. Elliot Smith, F.R.S.	Primitive Man.
	Sir E. Rutherford, F.R.S. ...	Atoms and Electrons.
Brisbane	Prof. H. E. Armstrong, F.R.S.	The Materials of Life.
	Prof. G. W. O. Howe	Wireless Telegraphy.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Lecture
1901. Glasgow ...	H. J. Mackinder, M.A..........	The Movements of Men by Land and Sea.
1902. Belfast......	Prof. L. C. Miall, F.R.S.	Gnats and Mosquitoes.
1903. Southport...	Dr. J. S. Flett	Martinique and St. Vincent: the Eruptions of 1902.
1904. Cambridge..	Dr. J. E. Marr, F.R.S.	The Forms of Mountains.
1906. York.........	Prof. S. P. Thompson, F.R.S.	The Manufacture of Light.
1907. Leicester...	Prof. H. A. Miers, F.R.S.......	The Growth of a Crystal.
1908. Dublin......	Dr. A. E. H. Tutton, F.R.S.	The Crystallisation of Water.
1910. Sheffield ...	C. T. Heycock, F.R.S.	Metallic Alloys.
1911. Portsmouth	Dr. H. R. Mill	Rain.

[1] 'Popular Lectures,' delivered to the citizens of Winnipeg.
[2] Repeated, to the public, on Wednesday, September 7.

PUBLIC OR CITIZENS' LECTURES.

Date and Place	Lecturer	Subject of Lecture
1912. Dundee ...	Prof. B. Moore, D.Sc.	Science and National Health.
	Prof. E. C. K. Gonner, M.A.	Prices and Wages.
	Prof. A. Fowler, F.R.S.	The Sun.
1913. Birmingham	Dr. A. C. Haddon, F.R.S. ...	The Decorative Art of Savages.
	Dr. Vaughan Cornish	The Panama Canal.
	Leonard Doncaster, M.A. ...	Recent Work on Heredity and its Application to Man.
	Dr. W. Rosenhain, F.R.S. ...	Metals under the Microscope.
	Frederick Soddy, F.R.S.	The Evolution of Matter.
1914. Australia:		
Perth ...	Prof. W. A. Herdman, F.R.S.	Why we Investigate the Ocean.
	Prof. A. S. Eddington, F.R.S.	Stars and their Movements.
	H. Balfour, M.A.	Primitive Methods of Making Fire.
	Prof. A. D. Waller, F.R.S. ...	Electrical Action of the Human Heart.
	C. A. Buckmaster, M.A.	Mining Education in England.
Adelaide	Prof. E. C. K. Gonner, M.A.	Saving and Spending.
Melbourne	Dr. W. Rosenhain, F.R.S.	Making of a Big Gun.
	Prof. H. B. Dixon, F.R.S. ...	Explosions.
Sydney ...	Prof. B. Moore, F.R.S..........	Brown Earth and Bright Sunshine.
	Prof. H. H. Turner, F.R.S. ...	Comets.
Brisbane	Dr. A. C. Haddon, F.R.S. ...	Decorative Art in Papua.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes, 1901-1913.

1901.

	£	s.	d.
Electrical Standards	45	0	0
Seismological Observations	75	0	0
Wave-length Tables	4	14	0
Isomorphous Sulphonic Derivatives of Benzene	35	0	0
Life-zones in British Carboniferous Rocks	20	0	0
Underground Water of North-west Yorkshire	50	0	0
Exploration of Irish Caves	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	75	0	0
Migration of Birds	10	0	0
Terrestrial Surface Waves	5	0	0
Changes of Land-level in the Phlegræan Fields	50	0	0
Legislation regulating Women's Labour	15	0	0
Small Screw Gauge	45	0	0
Resistance of Road Vehicles to Traction	75	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	30	0	0
Anthropological Teaching	5	0	0
Exploration in Crete	145	0	0
Physiological Effects of Peptone	30	0	0
Chemistry of Bone Marrow	5	15	11
Suprarenal Capsules in the Rabbit	5	0	0
Fertilisation in Phæophyceæ	15	0	0
Morphology, Ecology, and Taxonomy of Podostemaceæ	20	0	0
Corresponding Societies Committee	15	0	0
	£920	9	11

1902.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	35	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	80	0	0
Relation between Absorption Spectra and Organic Substances	20	0	0
Wave-length Tables	5	0	0
Life-zones in British Carboniferous Rocks	10	0	0
Exploration of Irish Caves	45	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Structure of Coral Reefs of Indian Ocean	50	0	0
Compound Ascidians of the Clyde Area	25	0	0
Terrestrial Surface Waves	15	0	0
Legislation regulating Women's Labour	30	0	0
Small Screw Gauge	20	0	0
Resistance of Road Vehicles to Traction	50	0	0
Ethnological Survey of Canada	15	0	0
Age of Stone Circles	30	0	0
Exploration in Crete	100	0	0
Anthropometric Investigation of Native Egyptian Soldiers	15	0	0
Excavations on the Roman Site at Gelligaer	5	0	0
Changes in Hæmoglobin	15	0	0
Work of Mammalian Heart under Influence of Drugs	20	0	0
Investigation of the Cyanophyceæ	10	0	0
Reciprocal Influence of Universities and Schools	5	0	0
Conditions of Health essential to carrying on Work in Schools	2	0	0
Corresponding Societies Committee	15	0	0
	£947	0	0

1903.

	£	s.	d.
Electrical Standards	35	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	75	0	0
Magnetic Observations at Falmouth	40	0	0
Study of Hydro-aromatic Substances	20	0	0
Erratic Blocks	10	0	0
Exploration of Irish Caves	40	0	0
Underground Waters of North-west Yorkshire	40	0	0

	£	s.	d.
Life-zones in British Carboniferous Rocks	5	0	0
Geological Photographs	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Generum et Specierum Animalium	100	0	0
Tidal Bore, Sea Waves, and Beaches	15	0	0
Scottish National Antarctic Expedition	50	0	0
Legislation affecting Women's Labour	25	0	0
Researches in Crete	100	0	0
Age of Stone Circles	3	13	2
Anthropometric Investigation	5	0	0
Anthropometry of the Todas and other Tribes of Southern India	50	0	0
The State of Solution of Proteids	20	0	0
Investigation of the Cyanophyceæ	25	0	0
Respiration of Plants	12	0	0
Conditions of Health essential for School Instruction	5	0	0
Corresponding Societies Committee	20	0	0
Anthropometric Investigation of Egyptian Troops	8	10	0
Excavations on Roman Sites in Britain	25	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	40	0	0
Botanical Photographs	4	8	11
Respiration of Plants	15	0	0
Experimental Studies in Heredity	35	0	0
Corresponding Societies Committee	20	0	0
	£887	18	11

1904.

	£	s.	d.
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	50	0	0
Magnetic Observations at Falmouth	60	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	25	0	0
Erratic Blocks	10	0	0
Life-zones in British Carboniferous Rocks	35	0	0
Fauna and Flora of the Trias	10	0	0
Investigation of Fossiliferous Drifts	50	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	60	0	0
Development in the Frog	15	0	0
Researches on the Higher Crustacea	15	0	0
British and Foreign Statistics of International Trade	25	0	0
Resistance of Road Vehicles to Traction	90	0	0
Researches in Crete	100	0	0
Researches in Glastonbury	25	0	0

1905.

	£	s.	d.
Electrical Standards	40	0	0
Seismological Observations	40	0	0
Investigation of the Upper Atmosphere by means of Kites	40	0	0
Magnetic Observations at Falmouth	50	0	0
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism	20	0	0
Aromatic Nitroamines	25	0	0
Fauna and Flora of the British Trias	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Generum et Specierum Animalium	75	0	0
Development of the Frog	10	0	0
Investigations in the Indian Ocean	150	0	0
Trade Statistics	4	4	8
Researches in Crete	75	0	0
Anthropometric Investigations of Egyptian Troops	10	0	0
Excavations on Roman Sites in Britain	10	0	0
Anthropometric Investigations	10	0	0
Age of Stone Circles	30	0	0
The State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	30	0	0
Ductless Glands	40	0	0
Botanical Photographs	3	17	6
Physiology of Heredity	35	0	0
Structure of Fossil Plants	50	0	0
Corresponding Societies Committee	20	0	0
	£928	2	2

1906.

	£	s.	d.
Electrical Standards	25	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	50	0	0
Magnetic Survey of South Africa	99	12	6
Wave-length Tables of Spectra	5	0	0
Study of Hydro-aromatic Substances	25	0	0
Aromatic Nitroamines	10	0	0
Fauna and Flora of the British Trias	7	8	11
Crystalline Rocks of Anglesey	30	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Frog	10	0	0
Higher Crustacea	15	0	0
Freshwater Fishes of South Africa	50	0	0
Rainfall and Lake and River Discharge	10	0	0
Excavations in Crete	100	0	0
Lake Village at Glastonbury	40	0	0
Excavations on Roman Sites in Britain	30	0	0
Anthropometric Investigations in the British Isles	30	0	0
State of Solution of Proteids	20	0	0
Metabolism of Individual Tissues	20	0	0
Effect of Climate upon Health and Disease	20	0	0
Research on South African Cycads	14	19	4
Peat Moss Deposits	25	0	0
Studies suitable for Elementary Schools	5	0	0
Corresponding Societies Committee	25	0	0
	£882	0	9

1907.

	£	s.	d.
Electrical Standards	50	0	0
Seismological Observations	40	0	0
Magnetic Observations at Falmouth	40	0	0
Magnetic Survey of South Africa	25	7	6
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	30	0	0
Life Zones in British Carboniferous Rocks	10	0	0
Erratic Blocks	10	0	0
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone of South-West England	15	0	0
Correlation and Age of South African Strata, &c.	10	0	0
Table at the Zoological Station, Naples	100	0	0
Index Animalium	75	0	0
Development of the Sexual Cells	1	11	8
Oscillations of the Land Level in the Mediterranean Basin	50	0	0
Gold Coinage in Circulation in the United Kingdom	8	19	7
Anthropometric Investigations in the British Isles	10	0	0
Metabolism of Individual Tissues	45	0	0
The Ductless Glands	25	0	0
Effect of Climate upon Health and Disease	55	0	0
Physiology of Heredity	30	0	0
Research on South African Cycads	35	0	0
Botanical Photographs	5	0	0
Structure of Fossil Plants	5	0	0
Marsh Vegetation	15	0	0
Corresponding Societies Committee	16	14	1
	£757	12	10

1908.

	£	s.	d.
Seismological Observations	40	0	0
Further Tabulation of Bessel Functions	15	0	0
Investigation of Upper Atmosphere by means of Kites	25	0	0
Meteorological Observations on Ben Nevis	25	0	0
Geodetic Arc in Africa	200	0	0
Wave-length Tables of Spectra	10	0	0
Study of Hydro-aromatic Substances	30	0	0
Dynamic Isomerism	40	0	0
Transformation of Aromatic Nitroamines	30	0	0
Erratic Blocks	17	16	6
Fauna and Flora of British Trias	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
Pre-Devonian Rocks	10	0	0
Exact Significance of Local Terms	5	0	0
Composition of Charnwood Rocks	10	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Hereditary Experiments	10	0	0
Fauna of Lakes of Central Tasmania	40	0	0
Investigations in the Indian Ocean	50	0	0

	£	s.	d.
Exploration in Spitsbergen ...	30	0	0
Gold Coinage in Circulation in the United Kingdom......	3	7	6
Electrical Standards	50	0	0
Glastonbury Lake Village ...	30	0	0
Excavations on Roman Sites in Britain	15	0	0
Age of Stone Circles...........	50	0	0
Anthropological Notes and Queries	40	0	0
Metabolism of Individual Tissues..........................	40	0	0
The Ductless Glands...........	13	14	8
Effect of Climate upon Health and Disease..................	35	0	0
Body Metabolism in Cancer...	30	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Marsh Vegetation	15	0	0
Succession of Plant Remains	18	0	0
Corresponding Societies Committee	25	0	0
	£1,157	18	8

1909.

	£	s.	d.
Seismological Observations ..	60	0	0
Investigation of the Upper Atmosphere by means of Kites	10	0	0
Magnetic Observations at Falmouth	50	0	0
Establishing a Solar Observatory in Australia	50	0	0
Wave-length Tables of Spectra	9	16	0
Study of Hydro-aromatic Substances	15	0	0
Dynamic Isomerism...........	35	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	30	0	0
Fauna and Flora of British Trias	8	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	8	0	0
Palæozoic Rocks of Wales and the West of England	9	0	0
Igneous and Associated Sedimentary Rocks of Glensaul	11	13	9
Investigations at Biskra	50	0	0
Table at the Zoological Station at Naples	100	0	0
Heredity Experiments.........	10	0	0
Feeding Habits of British Birds	5	0	0
Index Animalium..............	75	0	0
Investigations in the Indian Ocean	35	0	0
Gaseous Explosions	75	0	0
Excavations on Roman Sites in Britain	5	0	0
Age of Stone Circles...........	30	0	0
Researches in Crete	70	0	0
The Ductless Glands	35	0	0
Electrical Phenomena and Metabolism of *Arum Spadices*	10	0	0
Reflex Muscular Rhythm......	10	0	0
Anæsthetics	25	0	0
Mental and Muscular Fatigue	27	0	0
Structure of Fossil Plants ...	5	0	0
Botanical Photographs.........	10	0	0
Experimental Study of Heredity........................	30	0	0
Symbiosis between Turbellarian Worms and Algæ	10	0	0
Survey of Clare Island.........	65	0	0
Curricula of Secondary Schools	5	0	0
Corresponding Societies Committee	21	0	0
	£1,014	9	9

1910.

	£	s.	d.
Measurement of Geodetic Arc in South Africa............ ..	100	0	0
Republication of Electrical Standards Reports	100	0	0
Seismological Observations...	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Study of Hydro-aromatic Substances	25	0	0
Dynamic Isomerism...........	35	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	10	0	0
Faunal Succession in the Carboniferous Limestone in the British Isles	10	0	0
South African Strata	5	0	0
Fossils of Midland Coalfields	25	0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Heredity Experiments.........	15	0	0
Feeding Habits of British Birds	5	0	0
Amount and Distribution of Income	15	0	0
Gaseous Explosions	75	0	0
Lake Villages in the neighbourhood of Glastonbury...	5	0	0
Excavations on Roman Sites in Britain	5	0	0
Neolithic Sites in Northern Greece.....	5	0	0
The Ductless Glands	40	0	0
Body Metabolism in Cancer...	20	0	0
Anæsthetics	25	0	0
Tissue Metabolism	25	0	0
Mental and Muscular Fatigue	18	17	0
Electromotive Phenomena in Plants	10	0	0

	£	s.	d.
Structure of Fossil Plants ...	10	0	0
Experimental Study of Heredity	30	0	0
Survey of Clare Island	30	0	0
Corresponding Societies Committee	20	0	0
	£963	17	0

1911.

	£	s.	d.
Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	25	0	0
Grant to International Commission on Physical and Chemical Constants	30	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	25	0	0
Transformation of Aromatic Nitroamines	15	0	0
Electroanalysis	15	0	0
Influence of Carbon, &c., on Corrosion of Steel	15	0	0
Crystalline Rocks of Anglesey	2	0	0
Mammalian Fauna in Miocene Deposits, Bugti Hills, Baluchistan		0	0
Table at the Zoological Station at Naples	100	0	0
Index Animalium	75	0	0
Feeding Habits of British Birds	5	0	0
Belmullet Whaling Station...	30	0	0
Map of Prince Charles Foreland	30	0	0
Gaseous Explosions	90	0	0
Lake Villages in the neighbourhood of Glastonbury...	5	0	0
Age of Stone Circles	30	0	0
Artificial Islands in Highland Lochs	10	0	0
The Ductless Glands	40	0	0
Anæsthetics	20	0	0
Mental and Muscular Fatigue	25	0	0
Electromotive Phenomena in Plants	10	0	0
Dissociation of Oxy-Hæmoglobin	25	0	0
Structure of Fossil Plants ...	15	0	0
Experimental Study of Heredity	45	0	0
Survey of Clare Island	20	0	0
Registration of Botanical Photographs	10	0	0
Mental and Physical Factors involved in Education	10	0	
Corresponding Societies Committee		0	0
	£922	0	0

1912.

	£	s.	d.
Seismological Investigations	60	0	0
Magnetic Observations at Falmouth	25	0	0
Investigation of the Upper Atmosphere	30	0	0
Grant to International Commission on Physical and Chemical Constants	30	0	0
Further Tabulation of Bessel Functions	15	0	0
Study of Hydro-aromatic Substances	20	0	0
Dynamic Isomerism	30	0	0
Transformation of Aromatic Nitroamines	10	0	0
Electroanalysis	10	0	0
Study of Plant Enzymes	30	0	0
Erratic Blocks	5	0	0
Igneous and Associated Rocks of Glensaul, &c.	15	0	0
List of Characteristic Fossils	5	0	0
Sutton Bone Bed	15	0	0
Bembridge Limestone at Creechbarrow Hill	20	0	0
Table at the Zoological Station at Naples	50	0	0
Index Animalium	75	0	0
Belmullet Whaling Station...	20	0	0
Secondary Sexual Characters in Birds	10	0	0
Gaseous Explosions	60	0	0
Lake Villages in the neighbourhood of Glastonbury	5	0	0
Artificial Islands in Highland Lochs	10	0	0
Physical Character of Ancient Egyptians	40	0	0
Excavation in Easter Island	15	0	0
The Ductless Glands	35	0	0
Calorimetric Observations on Man	40	0	0
Structure of Fossil Plants ...	15	0	0
Experimental Study of Heredity	35	0	0
Survey of Clare Island	20	0	0
Jurassic Flora of Yorkshire	15	0	0
Overlapping between Secondary and Higher Education	1	18	6
Curricula, &c., of Industrial and Poor Law Schools	10	0	
Influence of School Books upon Eyesight	3	9	0
Corresponding Societies Committee	25	0	0
Collections illustrating Natural History of Isle of Wight	40	0	0
	£845	7	6

1913.

	£	s.	d.
Seismological Investigations	130	0	0
Investigation of the Upper Atmosphere	25	0	0
International Committee on Physical and Chemical Constants	40	0	0
Calculation of Mathematical Tables	20	0	0
Disposal of Copies of the 'Binary Canon'	4	9	0
Study of Hydro-aromatic *Substances*	15	0	0
Dynamic Isomerism	25	0	0
Transformation of *Aromatic* Nitroamines	15	0	0
Study of Plant Enzymes	25	0	0
Correlation of Crystalline Form with Molecular Structure	25	0	0
Study of Solubility Phenomena	10	0	0
List of Characteristic Fossils	5	0	0
Geology of Ramsey Island	10	0	0
Fauna and Flora of Trias of Western Midlands	10	0	0
Critical Sections in Lower Palæozoic Rocks	15	0	0
Belmullet Whaling Station	20	0	0
Nomenclature Animalium Genera et Sub-genera	50	0	0
Antarctic Whaling Industry	75	0	0
Maps for School and University Use	40	0	0
Gaseous Explosions	50	0	0
Stress Distributions in Engineering Materials	50	0	0
Lake Villages in the Neighbourhood of Glastonbury	20	0	0
Age of Stone Circles	20	0	0
Artificial Islands in the Highlands of Scotland	5	0	0
Excavations on Roman Sites in Britain	20	0	0
Anthropometric Investigations in Cyprus	50	0	0
Palæolithic Site in Jersey	50	0	0
The Ductless Glands	35	0	0
Calorimetric Observations on Man	40	0	0
Structure and Function of the Mammalian Heart	30	0	0
Binocular Combination of Kinematograph Pictures	0	17	0
Structure of Fossil Plants	15	0	0
Jurassic Flora of Yorkshire	5	0	0
Flora of the Peat of the Kennet Valley	15	0	0
Vegetation of Ditcham Park	14	4	3
Physiology of Heredity	30	0	0
Breeding Experiments with Œnotheras	19	17	4
Mental and Physical Factors involved in Education	20	0	0
Influence of School Books on Eyesight	2	8	9
Character, Work, and Maintenance of Museums	10	0	0
Corresponding Societies Committee	25	0	0
	£1,086	16	4

REPORT OF THE COUNCIL, 1913-14.

I. The Council have to record their profound sorrow at the death of Sir David Gill, F.R.S., ex-President. The following resolution was conveyed to Lady Gill by the President:—

> 'The Council deeply regret the death of their late distinguished President, Sir David Gill, whose personality was so widely appreciated, and whose work for Astronomy at the Cape Observatory elevated it to the first rank; and they empower the Officers to convey to Lady Gill and his family their profound sympathy.'

II. Professor A. Schuster, F.R.S., has been unanimously nominated by the Council to fill the office of President of the Association for 1915-16 (Manchester Meeting).

III. Caird Fund.—(*a*) *Resolutions referred by the General Committee to the Council for consideration and, if desirable, for action, were dealt with as follows:*—

(1) 'That the Council be asked to appoint a Committee to carry out the request of Sir J. K. Caird in his letter of September 10 (viz., that his further gift of £1,000 be earmarked for the study of Radio-Activity as a branch of Geo-Physics).'

It was resolved to appoint the following Committee to carry out the above request: The President and General Officers, Sir E. Rutherford, Mr. F. Soddy, and Sir J. J. Thomson. The Committee was empowered to add to its number and to modify the condition attaching to the above gift, subject to the approval of Sir J. K. Caird.

(2) 'That the request of Section A (Mathematics and Physics) for a grant from the Caird Fund of £500 for Radio-telegraphic investigations be sent to the Council for consideration and action.'

It was resolved that the above request be granted, and that the General Treasurer be empowered to pay the sum named to the Chairman of the Committee appointed to conduct the said investigations.

(3) 'That a grant of £100 for the coming year be made to the Committee on the Naples Table from the Caird Fund, and that the Council be requested to consider the advisability of endowing the Committee by a capital sum yielding an annual income of £100.'

It was resolved that a grant of £100 for the coming year be made to the Committee on the Naples Table from the Caird Fund, and that a grant of £100 be made annually in future to the Committee, subject to the adoption of its annual report.

(4) 'That a grant of £100 for the coming year be made to the Committee on Seismological Investigations from the Caird Fund, and that the Council be asked to consider the advisability of endowing the Committee by a capital sum yielding an annual income of £100.'

It was resolved that a grant of £100 for the coming year be made to the Committee on Seismological Investigations, and that a grant of £100 be made annually in future to the Committee, subject to the adoption of its annual report.

(*b*) An application to the Council from the 'Scotia' Publication Committee (Scottish Antarctic Expedition) for a grant of £400 from the Caird Fund towards the expenses of the publication of the 'Scientific Results of the Voyage of the "Scotia"' was considered, and it was resolved that the application could not be entertained.

IV. Resolutions referred to the Council by the General Committee at Birmingham for consideration, and, if desirable, for action, were dealt with as follows:—

From Sections A and E.

'That the terms First Order, Second Order, Third Order, and Fourth Order of triangulation, as connoting definite degrees of precision, be used to describe triangulation even though the terms now in use (*e.g.*, Major, Minor, &c.), which have only a local significance, are also employed.'

'That this resolution be communicated through the proper channels to (*a*) the Geodetic Association, and (*b*) the Institute of Surveyors.'

The Council approved the principle of the above resolution, and resolved that Professor H. H. Turner and Captain H. G. Lyons be appointed a Committee to communicate, in the name of the Council, with the Geodetic Association and the Institute of Surveyors. The Committee duly carried out this instruction.

From Section I.

'The Committee of Section I requests the Council of the Association to forward to the Board of Trade the following resolution:—

(i) That Colour Vision Tests are most efficiently conducted by means of what is known as the "Lantern Test."

(ii) That the best form of such lantern has not yet been finally decided upon, and can be arrived at only after further expert report.

(iii) That the actual application of sight tests requires the co-operation of an ophthalmic surgeon with a practical navigator.'

The Council, after careful consideration and consultation among members specially interested in this question, resolved to take no action.

From Section I.

'That in view of the fact that numerous deaths continue to take place from anæsthetics administered by unregistered persons, the Committee of the Section of Physiology of the British Association appeals to the Council of the Association to represent to the Home Office and to the Privy Council the urgent need of legislation to protect the public against such unnecessary risks.'

The Council appointed a Committee to consider and report upon the above resolution, and subsequently adopted the following resolution, which was transmitted to the Home Office:—

'The Council of the British Association desire to urge upon His Majesty's Government the necessity of introducing legislation on the subject of the administration of anæsthetics, as recommended by the Departmental Committee of the Home Office, dated March 18, 1910, but with the addition to Recommendation (3) of a clause permitting administration by unregistered persons under the immediate supervision of a person duly qualified. The Council would point out that the recommendations of the General Medical Council are practically identical with those of the Departmental Committee, and that these recommendations have been approved by various academic and professional bodies, and also by the Council of this Association in 1910.'

V. In connection with the Magnetic Re-survey of the British Isles, referred to in the Report of the Council for 1912-13, the Council agreed to the proposal of the Royal Society that a joint supervising committee of the Society and the Association be appointed, and the following members were appointed to represent the Association: Sir Oliver Lodge, Prof. J. Perry, Prof. H. H. Turner, Dr. C. Chree, Dr. S. Chapman, Dr. F. W. Dyson, Dr. R. T. Glazebrook.

The Council empowered the General Treasurer to pay from the Caird Fund a sum not exceeding £250 towards the cost of the Survey.

VI. Australian Meeting.—(i) At their meeting in December 1913 the Council were informed as to the limit of the total number of the oversea party which the Australian authorities had found it necessary to propose, having regard to the provision of suitable travelling facilities, &c., in Australia. The Council were also informed that by counting all doubtful or qualified intimations from members, and all applications for new membership, the limit above mentioned was already substantially exceeded. It was resolved (*a*) that there should be no more admissions to the oversea party, excepting any member whose attendance the Australian Committee or the General Officers (in consultation, if necessary, with representatives of any particular Section) might decide to be of special importance to the scientific work of the meeting; (*b*) that the General Secretaries should be empowered to desire members whose intimations were qualified by

doubt to express their definite intentions by a certain date; (*c*) that the General Officers should be empowered to take, in the name of the Council, any other measures which might appear necessary to effect a reduction in the total number of the oversea party.

(ii) Previously to the departure of Dr. A. C. D. Rivett, General Organising Secretary in Australia, from London in December 1913, it was resolved that the thanks of the Council be expressed to Dr. Rivett for the assistance he had rendered in connection with the arrangements for the meeting during his visit to England, and to the authorities in Australia under whose direction he had paid this visit.

VII. The Council resolved that the meetings of the Conference of Delegates of Corresponding Societies be held in Havre in August 1914 on the occasion of the meeting there of L'Association Française pour l'Avancement des Sciences.

In these circumstances the Council made the following appointments on behalf of the General Committee (in place of nominations, as usual):—

Conference of Delegates.—Sir H. G. Fordham (*Chairman*). Sir E. Brabrook (*Vice-Chairman*). Mr. W. Mark Webb (*Secretary*).

The following nominations are made by the Council:—

Corresponding Societies Committee.—Mr. W. Whitaker (*Chairman*), Mr. W. Mark Webb (*Secretary*), Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Dr. J. G. Garson, Principal E. H. Griffiths, Dr. A. C. Haddon, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.

VIII. The Council have received an intimation from the Town Clerk of Cardiff that the Council and other authorities in that city intend to present an invitation to the Association to hold there its Meeting in 1918.

IX. The Council have received reports from the General Treasurer during the past year. In consequence of the early removal of the books, &c., from London to Australia, it has not been possible to prepare the usual annual accounts. These will be audited and presented to the General Committee at the Manchester Meeting (1915).

X. The retiring members of the Council are:—

Sir D. Prain, Prof. C. S. Sherrington, Prof. F. T. Trouton, Dr. J. E. Marr, Prof. J. B. Farmer.

The Council nominated the following new members:—

Dr. F. W. Dyson,
Miss E. R. Saunders,
Prof. E. H. Starling,

leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of ordinary members is as follows:—

Prof. H. E. Armstrong.
Sir E. Brabrook.
Prof. W. H. Bragg.
Dr. Dugald Clerk.
Major P. G. Craigie.
W. Crooke.
Prof. A. Dendy.
Dr. F. A. Dixey.
Prof. H. B. Dixon.
Dr. F. W. Dyson.
Principal E. H. Griffiths.
Dr. A. C. Haddon.
A. D. Hall.
Prof. W. D. Halliburton.
Sir Everard im Thurn.
Alfred Lodge.
Capt. H. G. Lyons.
Prof. R. Meldola.
Prof. J. L. Myres.
Miss E. R. Saunders.
Prof. E. H. Starling
J. J. H. Teall.
Prof. S. P. Thompson.

XI. THE GENERAL OFFICERS have been nominated by the Council as follows:—

General Treasurer: Prof. J. Perry.
General Secretaries: Prof. W. A. Herdman.
Prof. H. H. Turner.

XII. The following have been admitted as members of the General Committee:—

Prof. H. S. Carslaw.
Prof. W. J. Dakin.
Prof. T. W. Edgeworth David.
Prof. W. G. Duffield.
Mr. A. du Toit.
Prof. A. J. Ewart.
Mr. J. T. Ewen.
Prof. H. J. Fleure.
Mr. Willoughby Gardner.
Prof. Kerr Grant.
Mr. C. Hedley.
Prof. W. A. Jolly.
Dr. C. F. Juritz.
Prof. T. Lyle.
Dr. H. McCombie.
Mr. J. H. Maiden.
Dr. R. R. Marett.
Prof. Orme Masson.
Dr. N. V. Sidgwick.
Prof. C. Michie Smith.
Prof. W. Baldwin Spencer.
Prof. B. D. Steele.
Prof. E. C. Stirling.
Dr. W. E. Sumpner.
Major A. J. N. Tremearne.

Dr. **THE GENERAL TREASURER IN ACCOUNT ADVANCEMENT OF SCIENCE,**

1913-1914. RECEIPTS.

	£	s.	d.	£	s.	d.
Balance brought forward				1,375	13	3
Life Compositions (including Transfers)				549	0	0
Annual Subscriptions				782	0	0
New Annual Members' Subscriptions				356	0	0
Sale of Associates' Tickets				1,266	0	0
Sale of Ladies' Tickets				290	0	0
Sale of Publications				248	2	0
Sir James Caird's Gift (Radio-activity Investigation)				1,000	0	0
Interest on Deposits:						
Lloyds Bank, Birmingham				52	0	10
Bank of Scotland, Dundee				2	16	11
Unexpended Balances of Grants returned:						
Fossil Plants	0	10	3			
Corresponding Societies Committee	1	14	8			
Jurassic Flora	3	14	1			
				5	19	0
Dividends on Investments:						
Consols	134	4	8			
India 3 per Cent. Stock	101	14	0			
Great Indian Peninsula Railway 'B' Annuity	29	1	6			
				265	0	2
Dividends on 'Caird Fund' Investments:						
London and North-Western Railway Consolidated 4 per Cent. Preference Stock	94	3	4			
London and South-Western Railway do. do.	94	3	4			
India 3½ per Cent. Stock	86	11	8			
Canada 3½ per Cent. Registered Stock	82	7	10			
				357	6	2
Australian Government Subsidy: 1914 Meeting				15,000	0	0

Mem.: Receipts on account of the Australian Meeting (1914), amounting to £243, are not included in this account, but are paid to a separate (No. 2) account at the Bank.

Investments.

Nominal Amount £	s.	d.		Value 30th June, 1914. £	s.	d.
5,701	10	5	2½ per Cent. Consolidated Stock	4,276	2	10
3,600	0	0	India 3 per Cent. Stock	2,700	0	0
879	14	9	£43 Great Indian Peninsula Railway 'B' Annuity (cost)	849	5	0
2,627	0	10	India 3½ per Cent. Stock, 'Caird Fund'	2,338	1	4
2,500	0	0	London and North-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'	2,500	0	0
2,500	0	0	London and South-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'	2,475	0	0
2,500	0	0	Canada 3½ per Cent. 1930–1950 Registered Stock, 'Caird Fund'	2,225	0	0
			Sir Frederick Bramwell's Gift:—			
78	12	7	Self-cumulating Consolidated Stock [To be awarded in 1931 for a paper dealing with the whole question of the Prime Movers of 1931, and especially with the then relation between steam engines and internal combustion engines.]			

£21,549 18 4

JOHN PERRY, *General Treasurer.*

WITH THE BRITISH ASSOCIATION FOR THE *Cr.*

July 1, 1913, to June 30, 1914.

1913-1914. **PAYMENTS.**

	£	s.	d.	£	s.	d.	£	s.	d.
Rent and Office Expenses							167	0	7
Salaries, &c.							758	11	9
Printing, Binding, &c.							1,215	8	10
Expenses of Birmingham Meeting							165	11	2
Payments on account of Australian Meeting							44	4	9
Grants to Research Committees:—									
Seismological Investigations				130	0	0			
Investigation of the Upper Atmosphere				25	0	0			
International Committee on Physical and Chemical Constants				40	0	0			
Calculation of Mathematical Tables				20	0	0			
Disposal of Copies of the 'Binary Canon'				4	9	0			
Study of Hydro-aromatic Substances				15	0	0			
Dynamic Isomerism				25	0	0			
Transformation of Aromatic Nitroamines				15	0	0			
Study of Plant Enzymes				25	0	0			
Correlation of Crystalline Form with Molecular Structure				25	0	0			
Study of Solubility Phenomena				10	0	0			
List of Characteristic Fossils				5	0	0			
Geology of Ramsey Island				10	0	0			
Fauna and Flora of Trias of Western Midlands				10	0	0			
Critical Sections in Lower Palæozoic Rocks				15	0	0			
Belmullet Whaling Station				20	0	0			
Nomenclature Animalium Genera et Sub-genera				50	0	0			
Antarctic Whaling Industry				75	0	0			
Maps for School and University Use				40	0	0			
Gaseous Explosions				50	0	0			
Stress Distributions in Engineering Materials				50	0	0			
Lake Villages in the neighbourhood of Glastonbury				20	0	0			
Age of Stone Circles				20	0	0			
Artificial Islands in the Highlands of Scotland				5	0	0			
Excavations on Roman Sites in Britain				20	0	0			
Anthropometric Investigations in Cyprus				50	0	0			
Palæolithic Site in Jersey				50	0	0			
The Ductless Glands				35	0	0			
Calorimetric Observations on Man				40	0	0			
Structure and Function of the Mammalian Heart				30	0	0			
Binocular Combination of Kinematograph Pictures				0	17	0			
Structure of Fossil Plants				15	0	0			
Jurassic Flora of Yorkshire				5	0	0			
Flora of the Peat of the Kennet Valley				15	0	0			
Vegetation of Ditcham Park				14	4	3			
Physiology of Heredity				30	0	0			
Breeding Experiments with Œnotheras				19	17	4			
Mental and Physical Factors involved in Education				20	0	0			
Influence of School Books on Eyesight				2	8	9			
Character, Work, and Maintenance of Museums				10	0	0			
Corresponding Societies Committee				25	0	0			
							1,086	16	4
Grants made from 'Caird Fund'							775	0	0
Amounts paid to Grantees from Australian Government Subsidy: 1914 Meeting							14,950	0	0
Balance at Lloyds Bank, Birmingham (including accrued Interest)				1,676	12	3			
Balance at Bank of England, Western Branch: On General Account	£933	1	10						
Less Overspent on 'Caird Fund'	226	6	6						
				706	15	4			
Petty Cash in hand				3	17	4			
							2,387	4	11
							£21,549	18	4

An Account of £864 6s. 6d. is outstanding due to Messrs. Spottiswoode & Co.

I have examined the above Account with the Books and Vouchers of the Association, and certify the same to be correct. I have also verified the Balance at the Bankers, and have ascertained that the Investments are registered in the names of the Trustees.

W. B. Keen, *Chartered Accountant.*
December 2, 1914.

Approved—

Edward Brabrook, } *Auditors.*
Herbert McLeod, }

GENERAL MEETINGS, 1914.

The General Meetings held in Australia will be found mentioned in the course of the Narrative on pp. 679, *seqq.* A Narrative of the Visit of Members to the Meeting of L'Association Française at Le Havre, with an account of the meetings held there, is given on p. 720.

OFFICERS OF SECTIONS AT THE AUSTRALIAN MEETING, 1914.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Prof. F. T. Trouton, F.R.S. (*in absentiâ*). *Vice-Presidents.*—Prof. E. W. Brown, F.R.S.; Prof. H. S. Carslaw, F.R.S.; Sir Oliver J. Lodge, F.R.S.; Prof. A. W. Porter, F.R.S.; Sir E. Rutherford, F.R.S. *Secretaries.*—Prof. A. S. Eddington, F.R.S. (*Recorder*); E. Gold, M.A.; Prof. S. B. McLaren, M.A.; A. O. Rankine D.Sc.; Prof. T. R. Lyle, F.R.S. (Local Sec., Melbourne); Prof. J. A. Pollock, D.Sc. (Local Sec., Sydney).

SECTION B.—CHEMISTRY.

President.—Prof. W. J. Pope, F.R.S. *Vice-Presidents.*—Prof. F. Clowes, D.Sc.; Prof. H. B. Dixon, F.R.S.; Prof. Orme Masson, F.R.S.; Prof. E. H. Rennie, D.Sc.; Prof. B. D. Steele, D.Sc. *Secretaries.*—A. Holt, D.Sc. (*Recorder*); N. V. Sidgwick, D.Sc.; D. Avery, M.Sc. (Local Sec., Melbourne); Prof. C. Fawsitt, D.Sc. (Local Sec., Sydney).

SECTION C.—GEOLOGY.

President.—Prof. Sir T. H. Holland, K.C.I.E., F.R.S. *Vice-Presidents.*—Prof. W. S. Boulton, D.Sc.; Prof. T. W. Edgeworth David, C.M.G.; H. Herman: Prof. W. J. Sollas, F.R.S.; Prof. Woolnough, D.Sc. *Secretaries.*—A. R. Dwerryhouse, D.Sc. (*Recorder*); Prof. S. H. Reynolds, M.A.; Prof. E. W. Skeats, D.Sc. (Local Sec., Melbourne); E. F. Pittman, A.R.S.M. (Local Sec., Sydney).

SECTION D.—ZOOLOGY.

President.—Prof. A. Dendy, D.Sc., F.R.S. *Vice-Presidents.*—Prof. C. B. Davenport; Prof. W. A. Haswell, F.R.S.; Prof. H. Jungersen; Dr. O. Maas; Prof. E. A. Minchin, F.R.S.; Prof. Baldwin Spencer, C.M.G., F.R.S. *Secretaries.*—Prof. H. W. Marett Tims, M.A., M.D. (*Recorder*); J. H. Ashworth, D.Sc.; R. Douglas Laurie, M.A.; T. S. Hall, D.Sc. (Local Sec., Melbourne); Prof. W. A. Haswell, D.Sc., F.R.S. (Local Sec., Sydney).

SECTION E.—GEOGRAPHY.

President.—Sir Charles P. Lucas, K.C.B., K.C.M.G. *Vice-Presidents.*—Prof. Guido Cora; Prof. T. W. Edgeworth David, C.M.G.; Capt. J. K. Davis; Prof. W. M. Davis; Sir John Forrest; Prof. A. Penck. *Secretaries.*—H. Yule Oldham, M.A. (*Recorder*); J. McFarlane, M.A.; J. A. Leach, M.Sc. (Local Sec., Melbourne); F. Poate (Local Sec., Sydney).

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—Prof. E. C. K. Gonner, M.A. *Vice-Presidents.*—S. Ball; T. R. Bavin; Denison Miller; H. Y. Braddon; Harrison Moore. *Secretaries.*—Prof. A. W. Kirkaldy, M.A., M.Com. (*Recorder*); Prof. H. O. Meredith, M.A., M.Com.; G. H. Knibbs, C.M.G. (Local Sec., Melbourne); Prof. R. F. Irvine, M.A. (Local Sec., Sydney).

SECTION G.—ENGINEERING.

President.—Prof. E. G. Coker, D.Sc. *Vice-Presidents.*—W. Davidson; H. Deane, M.A.; Prof. G. Forbes, F.R.S.; Col. J. Monash; Prof. J. E. Petavel, F.R.S. *Secretaries.*—Prof. G. W. O. Howe, M.Sc. (*Recorder*); Prof. W. M. Thornton, D.Sc.; Prof. H. Payne (Local Sec., Melbourne); Prof. W. H. Warren (Local Sec., Sydney).

SECTION H.—ANTHROPOLOGY.

President.—Sir Everard im Thurn, C.B., K.C.M.G. *Vice-Presidents.*—H. Balfour, M.A.; Dr. Etheridge; Dr. A. C. Haddon, F.R.S.; Prof. F. von Luschan; Prof. Baldwin Spencer, C.M.G., F.R.S.; Prof. E. C. Stirling, F.R.S. *Secretaries.*—R. R. Marett, M.A., D.Sc. (*Recorder*); B. Malinowski, Ph.D.; Prof. R. J. A. Berry, M.D. (Local Sec., Melbourne); Prof. J. T. Wilson, M.B., F.R.S. (Local Sec., Sydney).

SECTION I.—PHYSIOLOGY.

President.—Prof. Benjamin Moore, F.R.S. *Vice-Presidents.*—Prof. W. D. Halliburton, F.R.S.; Prof. Sir E. A. Schäfer, F.R.S.; Prof. E. C. Stirling, F.R.S. *Secretaries.*—Prof. P. T. Herring, M.D. (*Recorder*); Prof. T. H. Milroy, M.D.; Prof. W. A. Osborne, D.Sc. (Local Sec., Melbourne); Prof. Sir T. P. Anderson Stuart, M.D., LL.D. (Local Sec., Sydney).

SECTION K.—BOTANY.

President.—Prof. F. O. Bower, F.R.S. *Vice-Presidents.*—J. H. Maiden, F.L.S.; Miss E. R. Saunders, F.L.S.; Prof. A. C. Seward, F.R.S. *Secretaries.*—Prof. T. Johnson, D.Sc. (*Recorder*); Miss E. N. Thomas, D.Sc.; Prof. A. J. Ewart, D.Sc. (Local Sec., Melbourne); Prof. A. Anstruther Lawson, Ph.D., D.Sc. (Local Sec., Sydney).

SECTION L.—EDUCATIONAL SCIENCE.

President.—Prof. J. Perry, F.R.S. *Vice-Presidents.*—Prof. H. E. Armstrong, F.R.S.; C. A. Buckmaster, M.A.; G. T. Moody, D.Sc. *Secretaries.*—Prof. J. A. Green, M.A. (*Recorder*); C. A. Buckmaster, M.A.; J. Smyth, M.A. (Local Sec., Melbourne); P. Board, M.A. (Local Sec., Sydney).

SECTION M.—AGRICULTURE.

President.—A. D. Hall, F.R.S. *Vice-Presidents.*—E. S. Beaven, F.C.S.; Prof. T. B. Wood, M.A. *Secretaries.*—J. Golding, F.I.C. (*Recorder*); A. Lauder, D.Sc.; Prof. T. Cherry, M.Sc. (Local Sec., Melbourne); Prof. R. D. Watt, M.A. (Local Sec., Sydney).

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES (HAVRE, 1914).

Chairman.—Sir H. G. Fordham. *Vice-Chairman.*—Sir E. Brabrook. *Secretary.*—W. Mark Webb.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York †	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork *	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[Continued on p. l.

at Annual Meetings of the Association.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	*796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

[*Continued on p.* li.

Table showing the Attendances and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1901, Sept. 11	Glasgow.................	Prof. A. W. Rücker, D.Sc., Sec.R.S.	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15.... ..	South Africa	Prof. G. H. Darwin, LL.D., F.R.S. ...	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25......	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31	Sheffield....	Rev. Prof. T. G. Bonney, F.R.S. . . .	293	26
1911, Aug. 30	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S...............	288	14
1913, Sept. 10	Birmingham	Sir Oliver J. Lodge, F.R.S............ ...	376	40
1914, July-Sept....	Australia	Prof. W. Bateson, F.R.S.	172	13

¶ Including 848 Members of the South African Association.

‡‡ Grants from the Caird Fund are not included in this and subsequent sums.

ANALYSIS OF ATTENDANCES AT

[*The total attendances for the years* 1832,

Average attendance at 79 *Meetings* : 1858.

	Average Attendance
Average attendance at 5 Meetings beginning during *June, between* 1833 *and* 1860	1260
Average attendance at 4 Meetings beginning during *July, between* 1841 *and* 1907	1122
Average attendance at 32 Meetings beginning during *August, between* 1836 *and* 1911	1927
Average attendance at 37 Meetings beginning during *September, between* 1831 *and* 1913	1977
Attendance at 1 Meeting held in *October, Cambridge,* 1862 . .	1161

Meetings beginning during August.

Average attendance at—

4 Meetings beginning during the 1st week in *August*	(1st– 7th) .	1905
5 " " " " 2nd " " "	(8th–14th) .	2130
9 " " " " 3rd " " "	(15th–21st) .	1802
14 " " " " 4th " " "	(22nd–31st) .	1935

at Annual Meetings of the Association—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received during the Meeting	Sums paid on account of Grants for Scientific Purposes	Year
374	131	794	246	20	1912	£2046 0 0	£920 9 11	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90		365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937¶	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908
290**	162	789	90	7	1468	1623 0 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0 0	963 17 0	1910
349	61	414	81	31	1241	1176 0 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0 0	978 17 1‡‡	1913
139	4160‖	539‖	—	21	5044§	4873 0 0	1086 16 4	1914

** Including 137 Members of the American Association.

‖ Special arrangements were made for Members and Associates joining locally in Australia, see p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.

THE ANNUAL MEETINGS, 1831–1913.

1835, 1843, *and* 1844 *are unknown.*]

Meetings beginning during September.

Average attendance at—

	Average Attendance
13 Meetings beginning during the 1st week in *September* (1st– 7th).	2131
17 „ „ „ „ 2nd „ „ „ (8th–14th).	1906
5 „ „ „ „ 3rd „ „ „ (15th–21st).	2206
2 „ „ „ „ 4th „ „ „ (22nd–30th).	1025

Meetings beginning during June, July, and October.

Attendance at 1 Meeting (1845, June 19) beginning during the 3rd week in *June* (15th–21st)	1079
Average attendance at 4 Meetings beginning during the 4th week in *June* (22nd–30th)	1306
Attendance at 1 Meeting (1851, July 2) beginning during the 1st week in *July* (1st–7th)	710
Average attendance at 2 Meetings beginning during the 3rd week in *July* (15th–21st)	1066
Attendance at 1 Meeting (1907, July 31) beginning during the 5th week in *July* (29th–31st)	1647
Attendance at 1 Meeting (1862, October 1) beginning during the 1st week in *October* (1st–7th)	1161

LIST OF GRANTS: Australia, 1914.

Research Committees, etc., appointed on behalf of the General Committee at the Australian Meeting: August, 1914.

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants
Section A.—MATHEMATICS AND PHYSICS.		£ s. d
Seismological Observations.	*Chairman.*—Professor H. H. Turner. *Secretary.*—Professor J. Perry. Mr. Horace Darwin, Mr. C. Davison, Dr. R. T. Glazebrook, Mr. M. H. Gray, Professors J. W. Judd and C. G. Knott, Sir J. Larmor, Professor R. Meldola, Mr. W. E. Plummer, Dr. R. A. Sampson, Professor A. Schuster, Mr. J. J. Shaw, and Mr. G. W. Walker.	60 0 0*
Investigation of the Upper Atmosphere.	*Chairman.*—Dr. W. N. Shaw. *Secretary.*—Mr. E. Gold. Mr. C. J. P. Cave, Mr. W. H. Dines, Dr. R. T. Glazebrook, Sir J. Larmor, Professor J. E. Petavel, Professor A. Schuster, and Dr. W. Watson.	25 0 0
Annual Tables of Constants and Numerical Data, chemical, physical, and technological.	*Chairman.*—Sir W. Ramsay. *Secretary.*—Dr. W. C. McC. Lewis.	40 0 0
Calculation of Mathematical Tables.	*Chairman.*—Professor M. J. M. Hill. *Secretary.*—Professor J. W. Nicholson. Mr. J. R. Airey, Mr. T. W. Chaundy, Professor Alfred Lodge, Professor L. N. G. Filon, Sir G. Greenhill, and Professors E. W. Hobson, A. E. H. Love, H. M. Macdonald, and A. G. Webster.	30 0 0

* In addition, the Council was authorised to expend a sum not exceeding £70 for the printing of circulars, &c., in connection with the Committee on Seismological Observations.

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
SECTION B.—CHEMISTRY.		£ s. d.
The Study of Hydro-Aromatic Substances.	*Chairman.*—Professor W. H. Perkin. *Secretary.*—Professor A. W. Crossley. Dr. M. O. Forster, Dr. Le Sueur, and Dr. A. McKenzie.	15 0 0
Dynamic Isomerism.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. T. M. Lowry. Professor Sydney Young, Dr. Desch, Dr. J. J. Dobbie, and Dr. M. O. Forster.	40 0 0
The Transformation of Aromatic Nitroamines and allied substances, and its relation to Substitution in Benzene Derivatives.	*Chairman.*—Professor F. S. Kipping. *Secretary.*—Professor K. J. P. Orton. Dr. S. Ruhemann and Dr. J. T. Hewitt.	20 0 0
The Study of Plant Enzymes, particularly with relation to Oxidation.	*Chairman.*—Mr. A. D. Hall. *Secretary.*—Dr. E. F. Armstrong. Professor H. E. Armstrong, Professor F. Keeble, and Dr. E. J. Russell.	30 0 0
Correlation of Crystalline Form with Molecular Structure.	*Chairman.*—Professor W. J. Pope. *Secretary.*—Professor H. E. Armstrong. Mr. W. Barlow and Professor W. P. Wynne.	25 0 0
Study of Solubility Phenomena.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Dr. J. V. Eyre. Dr. E. F. Armstrong, Professor A. Findlay, Dr. T. M. Lowry, and Professor W. J. Pope.	10 0 0
Chemical Investigation of Natural Plant Products of Victoria.	*Chairman.*—Professor Orme Masson. *Secretary.*—Dr. Heber Green. Mr. J. Cronin, and Mr. P. R. H. St. John.	50 0 0
The Influence of Weather Conditions upon the Amounts of Nitrogen Acids in the Rainfall and the Atmosphere.	*Chairman.*—Professor Orme Masson. *Secretary.*—Mr. V. G. Anderson. Mr. D. Avery and Mr. H. A. Hunt.	40 0 0
Research on Non-Aromatic Diazonium Salts	*Chairman.*—Dr. F. D. Chattaway. *Secretary.*—Professor G. T. Morgan. Mr. P. G. W. Bayly and Dr. N. V. Sidgwick.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
SECTION C.—GEOLOGY.		£ s. d.
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman.*—Mr. R. H. Tiddeman. *Secretary.*—Dr. A. R. Dwerryhouse. Dr. T. G. Bonney, Mr. F. W. Harmer, Rev. S. N. Harrison, Dr. J. Horne, Mr. W. Lower Carter, Professor W. J. Sollas, and Messrs. W. Hill, J. W. Stather, and J. H. Milton.	5 0 0
To consider the preparation of a List of Characteristic Fossils.	*Chairman.*—Professor P. F. Kendall. *Secretary.*—Mr. W. Lower Carter. Mr. H. A. Allen, Professor W. S. Boulton, Professor G. Cole, Dr. A. R. Dwerryhouse, Professors J. W. Gregory, Sir T. H. Holland, G. A. Lebour, and S. H. Reynolds, Dr. Marie C. Stopes, Mr. Cosmo Johns, Dr. J. E. Marr, Dr. A. Vaughan, Professor W. W. Watts, Mr. H. Woods, and Dr. A. Smith Woodward.	10 0 0
The Old Red Sandstone Rocks of Kiltorcan, Ireland.	*Chairman.*—Professor Grenville Cole. *Secretary.*—Professor T. Johnson. Dr. J. W. Evans, Dr. R. Kidston, and Dr. A. Smith Woodward.	10 0 0
Fauna and Flora of the Trias of the Western Midlands.	*Chairman.*—Mr. G. Barrow. *Secretary.*—Mr. L. J. Wills. Dr. J. Humphreys, Mr. W. Campbell Smith, Mr. D. M. S. Watson, and Professor W. W. Watts.	10 0 0
To excavate Critical Sections in the Lower Palæozoic Rocks of England and Wales.	*Chairman.* — Professor W. W. Watts. *Secretary.* — Professor W. G. Fearnsides. Professor W. S. Boulton, Mr. E. S. Cobbold, Mr. V. C. Illing, Dr. Lapworth, and Dr. J. E. Marr.	15 0 0
SECTION D.—ZOOLOGY.		
To investigate the Biological Problems incidental to the Belmullet Whaling Station.	*Chairman.*—Dr. A. E. Shipley. *Secretary.*—Professor J. Stanley Gardiner. Professor W. A. Herdman, Rev. W. Spotswood Green, Mr. E. S. Goodrich, Professor H. W. Marett Tims, and Mr. R. M. Barrington.	45 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
Nomenclator Animalium Genera et Sub-genera.	*Chairman.*—Dr. Chalmers Mitchell. *Secretary.*—Rev. T. R. R. Stebbing. Dr. M. Laurie, Prof. Marett Tims, and Dr. A. Smith Woodward.	25 0 0
An investigation of the Biology of the Abrolhos Islands and the North-west Coast of Australia (north of Shark's Bay to Broome), with particular reference to the Marine Fauna.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor W. J. Dakin. Dr. J. H. Ashworth and Professor F. O. Bower.	40 0 0
To obtain, as nearly as possible, a representative Collection of Marsupials for work upon (*a*) the Reproductive Apparatus and Development, (*b*) the Brain.	*Chairman.*—Professor A. Dendy. *Secretaries.*—Professors T. Flynn and G. E. Nicholls. Professor E B. Poulton and Professor H. W. Marett Tims.	100 0 0

Section E.—GEOGRAPHY.

Subject for Investigation, or Purpose	Members of Committee	Grants
To investigate the Conditions determining the Selection of Sites and Names for Towns, with special reference to Australia.	*Chairman.*—Sir C. P. Lucas. *Secretary.*—Mr. H. Yule Oldham. Mr. G. G. Chisholm, Professor A. J. Herbertson, and Professor J. L. Myres.	20 0 0
The Hydrographical Survey of Stor Fjord, Spitsbergen, by Dr. W. S. Bruce.	*Chairman.*—Mr. G. G. Chisholm. *Secretary.*—Mr. J. McFarlane. Dr. R. N. Rudmose Brown, Capt. J. K. Davis, and Mr. H. Yule Oldham.	50 0 0
To aid in the preparation of a Bathymetrical Chart of the Southern Ocean between Australia and Antarctica.	*Chairman.*—Professor T. W. Edgeworth David. *Secretary.*—Capt. J. K. Davis. Professor J. W. Gregory, Sir C. P. Lucas, and Professor Orme Masson.	100 0 0

Section F.—ECONOMIC SCIENCE AND STATISTICS.

Subject for Investigation, or Purpose	Members of Committee	Grants
The question of Fatigue from the Economic Standpoint, if possible in co-operation with Section I, Sub-section of Psychology.	*Chairman.*—Professor Muirhead. *Secretary.*—Miss B. L. Hutchins. Miss A. M. Anderson, Professor F. A. Bainbridge, Mr. E. Cadbury, Professor S. J. Chapman, Mr. P. Sargant Florence, Professor Stanley Kent, Miss M. C. Matheson, Mrs. Meredith, Dr. C. S. Myers, Mr. J. W. Ramsbottom and Dr. Jenkins Robb.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
SECTION G.—ENGINEERING.		£ s. d.
The Investigation of Gaseous Explosions, with special reference to Temperature.	*Chairman.*—Dr. Dugald Clerk. *Secretary.*—Professor W. E. Dalby. Professors W. A. Bone, F. W. Burstall, H. L. Callendar, E. G. Coker, and H. B. Dixon, Drs. R. T. Glazebrook and J. A. Harker, Colonel H. C. L. Holden, Professors B. Hopkinson and J. E. Petavel, Captain H. Riall Sankey, Professor A. Smithells, Professor W. Watson, Mr. D. L. Chapman, and Mr. H. E. Wimperis.	50 0 0
To report on certain of the more complex Stress Distributions in Engineering Materials.	*Chairman.*—Professor J. Perry. *Secretaries.* — Professors E. G. Coker and J. E. Petavel. Professor A. Barr, Dr. Chas. Chree, Mr. Gilbert Cook, Professor W. E. Dalby, Sir J. A. Ewing, Professor L. N. G. Filon, Messrs. A. R. Fulton and J. J. Guest, Professors J. B. Henderson and A. E. H. Love, Mr. W. Mason, Sir Andrew Noble, Messrs. F. Rogers and W. A. Scoble, Dr. T. E. Stanton, and Mr. J. S. Wilson.	50 0 0
SECTION H.—ANTHROPOLOGY.		
To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Mr. Willoughby Gardner. Professor W. Ridgeway, Sir Arthur J. Evans, Sir C. H. Read, Mr. H. Balfour, and Dr. A. Bulleid.	20 0 0
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	*Chairman.*—Sir C. H. Read. *Secretary.*—Mr. H. Balfour. Dr. G. A. Auden, Professor W. Ridgeway, Dr. J. G. Garson, Sir A. J. Evans, Dr. R. Munro, Professors Boyd Dawkins and J. L. Myres, Mr. A. L. Lewis, and Mr. H. Peake.	20 0 0
To investigate the Physical Characters of the Ancient Egyptians.	*Chairman.*—Professor G. Elliot Smith. *Secretary.*—Dr. F. C. Shrubsall. Dr. F. Wood-Jones, Dr. A. Keith, and Dr. C. G. Seligman.	34 16 6

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
To conduct Anthropometric Investigations in the Island of Cyprus.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. F. C. Shrubsall. Dr. A. C. Haddon.	50 0 0
To excavate a Palæolithic Site in Jersey.	*Chairman.*—Dr. R. R. Marett. *Secretary.*—Colonel Warton. Dr. C. W. Andrews, Mr. H. Balfour, Dr. Dunlop, Mr. G. de Gruchy, and Professor A. Keith.	50 0 0
To conduct Archæological Investigations in Malta.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. T. Ashby. Mr. H. Balfour, Dr. A. C. Haddon, and Dr. R. R. Marett.	10 0 0
To prepare and publish Miss Byrne's Gazetteer and Map of the Native Tribes of Australia.	*Chairman.*—Professor Baldwin Spencer. *Secretary.*—Dr. R. R. Marett. Mr. H. Balfour.	20 0 0

Section I.—PHYSIOLOGY.

The Ductless Glands.	*Chairman.*—Sir E. A. Schäfer. *Secretary.*—Professor Swale Vincent. Professor A. B. Macallum, Dr. L. E. Shore, and Mrs. W. H. Thompson.	35 0 0
To acquire further knowledge, Clinical and Experimental, concerning Anæsthetics—general and local—with special reference to Deaths by or during Anæsthesia, and their possible diminution.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Sir F. W. Hewitt. Dr. Blumfeld, Mr. J. A. Gardner, and Dr. G. A. Buckmaster.	20 0 0
Electromotive Phenomena in Plants.	*Chairman.*—Dr. A. D. Waller. *Secretary.*—Mrs. Waller. Professors J. B. Farmer, T. Johnson, and Veley, and Dr. F. O'B. Ellison.	20 0 0
To investigate the Physiological and Psychological Factors in the production of Miners' Nystagmus.	*Chairman.*—Professor J. H. Muirhead. *Secretary.*—Dr. T. G. Maitland. Dr. J. Jameson Evans and Dr. C. S. Myers.	20 0 0
The Significance of the Electromotive Phenomena of the Heart.	*Chairman.*—Professor W. D. Halliburton. *Secretary.*—Dr. Florence Buchanan. Professor A. D. Waller.	20 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
Metabolism of Phosphates.	*Chairman.*—Professor W. A. Osborne. *Secretary.*—Miss Kincaid. Dr. Rothera.	20 0 0
SECTION K.—BOTANY.		
The Structure of Fossil Plants.	*Chairman.*—Professor F.W.Oliver. *Secretary.*—Professor F. E. Weiss. Mr. E. Newell Arber, Professor A. C. Seward, and Dr. D. H. Scott.	15 0 0
Experimental Studies in the Physiology of Heredity.	*Chairman.*—Professor F.F. Blackman. *Secretary.*—Mr. R. P. Gregory Professors Bateson and Keeble and Miss E. R. Saunders.	45 0 0
The Renting of Cinchona Botanic Station in Jamaica.	*Chairman.*—Professor F. O. Bower. *Secretary.*—Professor R. H Yapp. Professors R. Buller, F. W. Oliver, and F. E. Weiss.	25 0 0
To carry out a Research on the Influence of varying percentages of Oxygen and of various Atmospheric Pressures upon Geotropic and Heliotropic Irritability and Curvature.	*Chairman.*—Professor F. O. Bower. *Secretary.*—Professor A. J. Ewart. Professor F. F. Blackman.	50 0 0
The Collection and Investigation of Material of Australian Cycadaceæ, especially Bowenia from Queensland and Macrozaunia from West Australia.	*Chairman.*—Professor A. A. Lawson. *Secretary.*—Professor T. G. B. Osborn. Professor A. C. Seward.	25 0 0
To cut Sections of Australian Fossil Plants, with especial reference to a specimen of Zygopteris from Simpson's Station, Barraba, N.S.W.	*Chairman.*—Professor Lang. *Secretary.*—Professor T. G. B. Osborn. Professor T. W. E. David and Professor A. C. Seward.	25 0 0
SECTION L.—EDUCATIONAL SCIENCE.		
To inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.	*Chairman.*—Dr. C. S. Myers. *Secretary.*—Professor J. A. Green. Professor J. Adams, Dr. G. A. Auden, Sir E. Brabrook, Dr. W. Brown, Mr. C. Burt, Professor E. P. Culverwell, Mr. G. F. Daniell, Miss B. Foxley, Professor R. A. Gregory, Dr. C. W. Kimmins, Professor W. McDougall, Dr. T. P. Nunn, Dr. W. H. R. Rivers, Dr. F. C. Shrubsall, Mr. H. Bompas Smith, Dr. C. Spearman, and Mr. A. E. Twentyman.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants
		£ s. d.
The Influence of School Books upon Eyesight.	*Chairman.*—Dr. G. A. Auden. *Secretary.*—Mr. G. F. Daniell. Mr. C. H. Bothamley, Mr. W. D. Eggar, Professor R. A. Gregory, Mr. J. L. Holland, Dr. W. E. Sumpner, and Mr. Trevor Walsh.	5 0 0
To inquire into and report on the number, distribution and respective values of Scholarships, Exhibitions, and Bursaries held by University Students during their undergraduate course, and on funds private and open available for their augmentation.	*Chairman.*—Sir Henry Miers. *Secretary.*—Professor Marcus Hartog. Miss Lilian J. Clarke, Miss B. Foxley, Professor H. Bompas Smith, and Principal Griffiths.	5 0 0
To examine, inquire into, and report on the Character, Work, and Maintenance of Museums, with a view to their Organisation and Development as Institutions for Education and Research; and especially to inquire into the Requirements of Schools.	*Chairman.*—Professor J. A. Green. *Secretaries.*—Mr. H. Bolton and Dr. J. A. Clubb. Dr. F. A. Bather, Mr. C. A. Buckmaster, Mr. Ernest Gray, Mr. M. D. Hill, Dr. W. E. Hoyle, Professors E. J. Garwood and P. Newberry, Sir Richard Temple, Mr. H. Hamshaw Thomas, Professor F. E. Weiss, Mrs. J. White, Rev. H. Browne, Drs. A. C. Haddon and H. S. Harrison, Mr. Herbert R. Rathbone, and Dr. W. M. Tattersall.	20 0 0

CORRESPONDING SOCIETIES.

Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. W. Mark Webb. Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Dr. J. G. Garson, Principal E. H. Griffiths, Dr. A. C. Haddon, Mr. T. V. Holmes, Mr. J. Hopkinson, Mr. A. L. Lewis, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.	25 0 0

2. *Not receiving Grants of Money.**

Subject for Investigation, or Purpose	Members of Committee
Section A.—MATHEMATICS AND PHYSICS.	
Radiotelegraphic Investigations.	*Chairman.*—Sir Oliver Lodge. *Secretary.*—Dr. W. H. Eccles. Mr. S. G. Brown, Dr. C. Chree, Professor A. S. Eddington, Dr. Erskine-Murray, Professors J. A. Fleming, G. W. O. Howe, H. M. Macdonald, and J. W. Nicholson, Sir H. Norman, Captain H. R. Sankey, Dr. A. Schuster, Dr. W. N. Shaw, Professor S. P. Thompson, and Professor H. H. Turner.
To aid the work of Establishing a Solar Observatory in Australia.	*Chairman.*— *Secretary.*—Dr. W. G. Duffield. Rev. A. L. Cortie, Dr. W. J. S. Lockyer, Mr. F. McClean, and Professors A. Schuster and H. H. Turner.
*Determination of Gravity at Sea.	*Chairman.*—Professor A. E. Love. *Secretary.*—Professor W. G. Duffield. Mr. T. W. Chaundy and Professors A. S. Eddington and H. H. Turner.
Section B.—CHEMISTRY.	
Research on the Utilization of Brown Coal Bye-Products.	*Chairman.*—Professor Orme Masson. *Secretary.*—Mr. P. G. W. Bayly. Mr. D. Avery.
To report on the Botanical and Chemical Characters of the Eucalypts and their Correlation.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Mr. H. G. Smith. Dr. Andrews, Mr. R. T. Baker, Professor F. O. Bower, Mr. R. H. Cambage, Professor A. J. Ewart, Professor C. B. Fawsitt, Dr. Heber Green, Dr. Cuthbert Hall, Professors Orme Masson, Rennie, and Robinson, and Mr. St. John.
Section C.—GEOLOGY.	
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretaries.*—Professors W. W. Watts and S. H. Reynolds. Mr. G. Bingley, Dr. T. G. Bonney, Mr. C. V. Crook, Professor E. J. Garwood, and Messrs. R. Kidston, A. S. Reid, J. J. H. Teall, R. Welch, and W. Whitaker.
To consider the Preparation of a List of Stratigraphical Names, used in the British Isles, in connection with the Lexicon of Stratigraphical Names in course of preparation by the International Geological Congress.	*Chairman.*—Dr. J. E. Marr. *Secretary.*—Dr. F. A. Bather. Professor Grenville Cole, Mr. Bernard Hobson, Professor Lebour, Dr. J. Horne, Dr. A. Strahan, and Professor W. W. Watts.

* Excepting the case of Committees receiving grants from the Caird Fund (p. lxviii).

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
To consider the Nomenclature of the Carboniferous, Permo-Carboniferous, and Permian Rocks of the Southern Hemisphere.	*Chairman.*—Professor T. W. Edgeworth David. *Secretary.*—Professor E. W. Skeats. Mr. W. S. Dun, Sir T. H. Holland, Professor Howchin, Mr. G. W. Lamplugh, and Professor W. G. Woolnough.

SECTION D.—ZOOLOGY.

*To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Mr. E. S. Goodrich. *Secretary.*—Dr. J. H. Ashworth. Mr. G. P. Bidder, Professor F. O. Bower, Drs. W. B. Hardy and S. F. Harmer, Professor S. J. Hickson, Sir E. Ray Lankester, Professor W. C. McIntosh, and Dr. A. D. Waller.
To investigate the Feeding Habits of British Birds by a study of the contents of the crops and gizzards of both adults and nestlings, and by collation of observational evidence, with the object of obtaining precise knowledge as to the economic status of many of our commoner birds affecting rural science.	*Chairman.*—Dr. A. E. Shipley. *Secretary.*—Mr. H. S. Leigh. Mr. J. N. Halbert, Professor Robert Newstead, Messrs. Clement Reid, A. G. L. Rogers, and F. V. Theobald, Professor F. E. Weiss, Dr. C. Gordon Hewitt, and Professors S. J. Hickson, F. W. Gamble, G. H. Carpenter, and J. Arthur Thomson.
To defray expenses connected with work on the Inheritance and Development of Secondary Sexual Characters in Birds.	*Chairman.*—Professor G. C. Bourne. *Secretary.*—Mr. Geoffrey Smith. Mr. E. S. Goodrich, Dr. W. T. Calman, and Dr. Marett Tims.
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology or Zoologists, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the Organisation.	*Chairman.*—Sir E. Ray Lankester. *Secretary.*—Professor S. J. Hickson. Professors G. C. Bourne, J. Cossar Ewart, M. Hartog, and W. A. Herdman, Mr. M. D. Hill, Professors J. Graham Kerr and Minchin, Dr. P. Chalmers Mitchell, Professors E. B. Poulton and Stanley Gardiner, and Dr. A. E. Shipley.
To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman* and *Secretary.*—Professor A. Dendy. Sir E. Ray Lankester, Professor J. P. Hill, and Mr. E. S. Goodrich.
To formulate a Definite System on which Collectors should record their captures.	*Chairman.*—Professor J. W. H. Trail. *Secretary.*—Mr. F. Balfour Browne. Drs. Scharff and E. J. Bles, Professors G. H. Carpenter and E. B. Poulton, and Messrs. A. G. Tansley and R. Lloyd Praeger.

* See note on preceding page.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
A Natural History Survey of the Isle of Man.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. P. M. C. Kermode. Dr. W. T. Calman, Rev. J. Davidson, Mr. G. W. Lamplugh, Professor E. W. MacBride, and Lord Raglan.

SECTION E.—GEOGRAPHY.

To inquire into the choice and style of Atlas, Textual, and Wall Maps for School and University Use.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Rev. W. J. Barton. Professors R. L. Archer and R. N. R. Brown, Mr. G. G. Chisholm, Professor H. N. Dickson, Mr A. R. Hinks, Mr O. J. R. Howarth, Sir Duncan Johnston, and Mr. E. A. Reeves.

SECTION G.—ENGINEERING.

To consider and report on the Standardization of Impact Tests.	*Chairman.*—Professor W. H. Warren. *Secretary.*—Mr J. Vicars. Mr. Julius, Professor Gibson, Mr. Houghton, and Professor Payne.

SECTION H.—ANTHROPOLOGY.

The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Sir C. H. Read. *Secretary.*— Dr. G. A. Auden, Mr E. Heawood, and Professor J. L. Myres.
To conduct Archæological and Ethnological Researches in Crete.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Professor J. L. Myres. Professor R. C. Bosanquet, Dr. W. L. H. Duckworth, Sir A. J. Evans, Professor W. Ridgeway, and Dr. F. C. Shrubsall.
To report on the present state of knowledge of the Prehistoric Civilisation of the Western Mediterranean with a view to future research.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Dr. T. Ashby. Dr W. L. H. Duckworth, Mr. D. G. Hogarth, Sir A. J. Evans, Professor J. L. Myres, and Mr. A. J. B. Wace.
To conduct Excavations in Easter Island.	*Chairman.*—Dr. A. C. Haddon. *Secretary.*—Dr. W. H. R. Rivers. Mr. R. R. Marett and Dr. C. G. Seligman.
To report on Palæolithic Sites in the West of England.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Dr. W. L. H. Duckworth. Professor A. Keith.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
The Teaching of Anthropology.	*Chairman.*—Sir Richard Temple. *Secretary.*—Dr. A. C. Haddon. Sir E. F. im Thurn, Mr. W. Crooke, Dr. C. G. Seligman, Professor G. Elliot Smith, Dr. R. R. Marett, Professor P. E. Newberry, Dr. G. A. Auden, Professors T. H. Bryce, P. Thompson, R. W. Reid, H. J. Fleure, and J. L. Myres, Sir B. C. A. Windle, and Professors R. J. A. Berry, Baldwin Spencer, Sir T. Anderson Stuart, and E. C. Stirling.
To excavate Early Sites in Macedonia.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Mr. A. J. B. Wace. Professors R. C. Bosanquet and J. L. Myres.
To report on the Distribution of Bronze Age Implements.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Mr. H. Peake. Professor W. Ridgeway, Mr. H. Balfour, Sir C. H. Read, Professor W. Boyd Dawkins, and Dr. R. R. Marett.
To investigate and ascertain the Distribution of Artificial Islands in the lochs of the Highlands of Scotland.	*Chairman.—Professor Boyd Dawkins. Secretary.—Prof. J. L. Myres.* Professors T. H. Bryce and W. Ridgeway, Dr. A. Low, and Mr. A. J. B. Wace.
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	*Chairman.*—Professor W. Ridgeway. *Secretary.*—Professor R. C. Bosanquet. Dr. T. Ashby, Mr. Willoughby Gardner, and Professor J. L. Myres.

SECTION I.—PHYSIOLOGY.

The Dissociation of Oxy-Hæmoglobin at High Altitudes.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Dr. J. Barcroft. Dr. W. B. Hardy.
Colour Vision and Colour Blindness.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Dr. Edridge-Green. Professor Leonard Hill, Professor A. W. Porter, Dr. A. D. Waller, Professor C. S. Sherrington, and Dr. F. W. Mott.
Calorimetric Observations on Man in Health and in Febrile Conditions.	*Chairman.*—Professor J. S. Macdonald. *Secretary.*—Dr. Francis A. Duffield. Dr. Keith Lucas.
Further Researches on the Structure and Function of the Mammalian Heart.	*Chairman.*—Professor C. S. Sherrington. *Secretary.*—Professor Stanley Kent. Dr. Florence Buchanan.
The Binocular Combination of Kinematograph Pictures of different Meaning, and its relation to the Binocular Combination of simpler Perceptions.	*Chairman.*—Dr. C. S. Myers. *Secretary.*—T. H. Pear.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee
Section K.—BOTANY.	
To consider and report on the advisability and the best means of securing definite Areas for the Preservation of Types of British Vegetation.	*Chairman.*—Professor F. E. Weiss. *Secretary.*—Mr. A. G. Tansley. Professor J. W. H. Trail, Mr. R. Lloyd Praeger, Professor F. W. Oliver, Professor R. W. Phillips, Dr. C. E. Moss, and Messrs. G. C. Druce and H. W. T. Wager.
The Investigation of the Vegetation of Ditcham Park, Hampshire.	*Chairman.*—Mr. A. G. Tansley. *Secretary.*—Mr. R. S. Adamson. Dr. C. E. Moss and Professor R. H. Yapp.
Section L.—EDUCATIONAL SCIENCE.	
To take notice of, and report upon changes in, Regulations—whether Legislative, Administrative, or made by Local Authorities — affecting Secondary and Higher Education.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Major E. Gray. Miss Coignan, Principal Griffiths, Dr. C. W. Kimmins, Sir Horace Plunkett, Mr. H. Ramage, Professor M. E. Sadler, and Rt. Rev. J. E. C. Welldon.
The Aims and Limits of Examinations.	*Chairman.*—Professor M. E. Sadler. *Secretary.*—Mr. P. J. Hartog. Mr. D. P. Berridge, Professor G. H. Bryan, Mr. W. D. Eggar, Professor R. A. Gregory, Principal E. H. Griffiths, Miss C. L. Laurie, Dr. W. McDougall, Mr. David Mair, Dr. T. P. Nunn, Sir W. Ramsay, Rt. Rev. J. E. C. Welldon, Dr. Jessie White, and Mr. G. U. Yule.

Communications ordered to be printed in extenso.

Section A.—Joint Discussion with Section B on the Structure of Atoms and Molecules.

Section A.—Dr. E. Goldstein: Salts coloured by Cathode Rays.

Section C.—Discussion on Physiography of Arid Lands.

Section D.—Discussion on Antarctica.

Section I.—Dr. J. W. Barrett: The Problem of the Visual Requirements of the Sailor and the Railway Employee.

Section M.—Dr. Lyman J. Briggs: Dry-farming Investigations in the United States.

Resolutions referred to the Council for consideration, and, if desirable, for action.

(a) *From Sections A and C.*

'That in view of the fact that meteorites, which convey information of world-wide importance, are sometimes disposed of privately, in such a way as to deprive the public of this information, the Council be requested to take such steps as may initiate international legislation on the matter.'

(b) *From Section A.*

'That the British Association respectfully urge the need for the establishment in Australia of a Bureau of Weights and Measures, with the view of legalising the

metric system as an alternative standard (as in Great Britain). They would also cordially welcome the inclusion of Australia as a member of the International Convention.'

(c) *From Section A.*

'That the British Association learns with great satisfaction that the State Government of Victoria has put a definite annual grant at the disposal of the Director of the Melbourne Observatory for printing the work already done at the Observatory. It is very desirable that every effort should be made to publish as soon as possible the arrears accumulated during the past thirty years.'

(d) *From Sections C and E.*

'The Committees of the Geographical and Geological Sections of the British Association wish to draw attention to the high scientific value and practical importance of systematic glacial observation in New Zealand, and venture to urge upon the favourable consideration of the Government of the Dominion the great importance of continuing and extending the work which is now being done in this direction by officers of the Government, as far as possible in conformity with the methods adopted by the Commission Internationale des Glaciers.'

(e) *From Sections C and E.*

'The Geographical and Geological Sections of the British Association respectfully request the Secretary of State for the Colonies to establish on certain islands in the Coral Seas—in extension of a plan that has lately been presented to His Excellency the Governor of Fiji, and by him submitted for the favourable consideration of the Legislative Council of that Colony—a number of bench-marks, with respect to which the mean level of the sea surface shall be accurately determined once every ten years, in order to discover, after a century or longer, whether any change takes place in the altitude of land with respect to the sea.

'It is suggested that a uniform plan for this work be prepared by the appropriate Government department, and that an abstract of the results obtained for each decade be forwarded to the British Association for publication.'

(f) *From Section C.*

'That the Committee of Section C submits for favourable consideration to the committee of Recommendations of the British Association the question of urging the Federal and State Governments in Australia to co-operate in undertaking, as soon as possible, a gravity survey of the Earth's crust within the area of the Commonwealth. The Committee suggests that the work be commenced in the region of the Great Rift Valley of Australia, extending from near Adelaide northwards to Lake Eyre.'

(g) *From Section E.*

'The Committee of Section E most warmly favours the project of a uniform Map of the World on a scale of 1 : 1,000,000, and expresses the hope that the sheets of Australia may be undertaken as soon as possible, on the same plan as has lately been adopted by the War Office in London for a map of Africa, and by the Geological Survey in Washington for the U.S.A. To this end they regard it as desirable that in the extensive surveys which the several States of the Commonwealth are carrying on, as much stress should be laid upon the geographical features of the land, the watercourses and the mountains, as upon property boundaries, and that in particular the determination of altitudes should be carried on, in order eventually to provide the basis for contoured maps.'

(h) *From Sections D and K.*

'It is with much pleasure that we ascertain that a Bill has been prepared by the present Government of South Australia for the establishment of a reserve of 300 square miles situated on the western end of Kangaroo Island for the preservation of the fauna and flora, which are fast being exterminated on the mainland, and that this reserve will be placed under the control of a Board nominated by the University of Adelaide and the Government. We trust that this Bill will become law at an early date.'

(i) *From the Committee of Recommendations.*

'That in view of the successful issue of the Australian Meeting of the Association, the Council be asked to consider the best means of bringing into closer relationship the British Association and scientific representatives from the Dominions overseas.'

Synopsis of Grants of Money (exclusive of Grants from the Caird Fund) appropriated for Scientific Purposes on behalf of the General Committee at the Australian Meeting, September 1914. The Names of Members entitled to call on the General Treasurer for the Grants are prefixed to the respective Research Committees.

Section A.—Mathematical and Physical Science.

	£	s.	d.
*Turner, Professor H. H.—Seismological Observations	†60	0	0
*Shaw, Dr. W. N.—Upper Atmosphere	25	0	0
*Ramsay, Sir W.—Annual Table of Constants and Numerical Data	40	0	0
*Hill, Professor M. J. M.—Calculation of Mathematical Tables	30	0	0

Section B.—Chemistry.

*Perkin, Dr. W. H.—Study of Hydro-aromatic Substances	15	0	0
*Armstrong, Professor H. E.—Dynamic Isomerism	40	0	0
*Kipping, Professor F. S.—Transformation of Aromatic Nitroamines	20	0	0
*Hall, A. D.—Study of Plant Enzymes	30	0	0
*Pope, Professor W. J.—Correlation of Crystalline Form with Molecular Structure	25	0	0
*Armstrong, Professor H. E.—Solubility Phenomena	10	0	0
Masson, Professor Orme.—Chemical Investigation of Natural Plant Products	50	0	0
Masson, Professor Orme.—Influence of Weather Conditions on Nitrogen Acids in Rainfall	40	0	0
Chattaway, Dr. F. D.—Non-aromatic Diazonium Salts	10	0	0

Section C.—Geology.

*Tiddeman, R. H.—Erratic Blocks	5	0	0
*Kendall, Professor P. F.—List of Characteristic Fossils	10	0	0
*Cole, Professor Grenville.—Old Red Sandstone Rocks of Kiltorcan	10	0	0
*Barrow, G.—Trias of Western Midlands	10	0	0
*Watts, Professor W. W.—Sections in Lower Palæozoic Rocks	15	0	0
Carried forward	£445	0	0

* Reappointed

† In addition, the Council are authorised to expend a sum not exceeding £70 on the printing of circulars, &c., in connection with the Committee on Seismological Observations.

	£	s.	d.
Brought forward	445	0	0
Section D.—Zoology.			
*Shipley, Dr. A. E.—Belmullet Whaling Station	45	0	0
*Mitchell, Dr. Chalmers.—Nomenclator Animalium	25	0	0
Herdman, Professor W. A.—Biology of Abrolhos Islands	40	0	0
Dendy, Professor A.—Collection of Marsupials	100	0	0
Section E.—Geography.			
Lucas, Sir C. P.—Conditions determining Selection of Sites and Names for Towns	20	0	0
Chisholm, G. G.—Survey of Stor Fjord, Spitsbergen	50	0	0
David, Professor T. W. E.—Antarctic Bathymetrical Chart	100	0	0
Section F.—Economic Science and Statistics.			
*Muirhead, Professor J. F.—Fatigue from Economic Standpoint	30	0	0
Section G.—Engineering.			
*Clerk, Dr. Dugald.—Gaseous Explosions	50	0	0
*Perry, Professor J.—Stress Distributions	50	0	0
Section H.—Anthropology.			
*Dawkins, Professor Boyd.—Lake Villages in the neighbourhood of Glastonbury	20	0	0
*Read, Sir C. H.—Age of Stone Circles	20	0	0
*Smith, Professor G. Elliot.—Physical Characters of the Ancient Egyptians	34	16	6
*Myres, Professor J. L.—Anthropometric Investigations in Cyprus	50	0	0
*Marett, Dr. R. R.—Palæolithic Site in Jersey	50	0	0
Myres, Professor J. L.—Excavations in Malta	10	0	0
Spencer, Professor Baldwin.—Gazetteer and Map of Native Tribes of Australia	20	0	0
Section I.—Physiology			
*Schäfer, Sir E. A.—The Ductless Glands	35	0	0
*Waller, Dr. A. D.—Anæsthetics	20	0	0
*Waller, Dr. A. D.—Electromotive Phenomena in Plants	20	0	0
*Muirhead, Professor J. F.—Miners' Nystagmus	20	0	0
Osborne, Professor W. A.—Metabolism of Phosphates	20	0	0
Halliburton, Professor W. D.—Electromotive Phenomena of the Heart	20	0	0
Section K.—Botany.			
*Oliver, Professor F. W.—Structure of Fossil Plants	15	0	0
*Blackman, Professor F. F.—Physiology of Heredity	45	0	0
*Bower, Professor F. O.—Renting of Cinchona Botanic Station, Jamaica	25	0	0
Carried forward	£1,379	16	6

* Reappointed.

	£	s.	d.
*Brought forward	1,379	16	6
Bower, Professor F. O.—Influence of Percentages of Oxygen, &c., on Geotropic and Heliotropic Irritation and Curvature	50	0	0
Lawson, Professor A. A.—Australian Cycadaceæ	25	0	0
Lang, Professor W. H.—Sections of Australian Fossil Plants	25	0	0
Section L.—Education.			
*Myers, Dr. C. S.—Mental and Physical Factors involved in Education	30	0	0
*Auden, Dr. G. A.—Influence of School Books on Eyesight	5	0	0
*Miers, Sir H.—Scholarships, &c., held by University Students	5	0	0
*Green, Professor J. A.—Character, Work, and Maintenance of Museums	20	0	0
Corresponding Societies Committee.			
*Whitaker, W.—For Preparation of Report	25	0	0
Total†	£1,634	16	6

* Reappointed.

† Including £70 as specified in footnote on p. lxvi.

Caird Fund.

An unconditional gift of 10,000*l.* was made to the Association at the Dundee Meeting, 1912, by Mr. (afterwards Sir) J. K. Caird, LL.D., of Dundee.

The Council in its Report to the General Committee at the Birmingham Meeting made certain recommendations as to the administration of this Fund. These recommendations were adopted, with the Report, by the General Committee at its meeting on September 10, 1913.

The following allocations have been made from the Fund by the Council to December 1914 :—

Naples Zoological Station Committee (p. lxi).—50*l.* (1912–13) ; 100*l.* (1913–14) ; 100*l.* annually in future, subject to the adoption of the Committee's report.

Seismology Committee (p. lii).—100*l.* (1913–14) ; 100*l.* annually in future, subject to the adoption of the Committee's report.

Radiotelegraphic Committee (p. lx). 500*l.* (1913–14).

Magnetic Re-survey of the British Isles (in collaboration with the Royal Society).—250*l.*

Committee on Determination of Gravity at Sea (p. lx).—100*l.* (1914–15).

Mr. F. Sargent, Bristol University, in connection with his Astronomical Work.—10*l.* (1914).

Sir J. K. Caird, on September 10, 1913, made a further gift of 1,000*l.* to the Association, to be devoted to the study of Radio-activity.

PRESIDENT'S ADDRESS.

ADDRESS

BY

PROFESSOR WILLIAM BATESON, M.A., F.R.S.,

PRESIDENT.

PART I.—MELBOURNE.[1]

THE outstanding feature of this Meeting must be the fact that we are here—in Australia. It is the function of a President to tell the Association of advances in science, to speak of the universal rather than of the particular or the temporary. There will be other opportunities of expressing the thoughts which this event must excite in the dullest heart, but it is right that my first words should take account of those achievements of organisation and those acts of national generosity by which it has come to pass that we are assembled in this country. Let us, too, on this occasion, remember that all the effort, and all the goodwill, that binds Australia to Britain would have been powerless to bring about such a result had it not been for those advances in science which have given man a control of the forces of Nature. For we are here by virtue of the feats of genius of individual men of science, giant-variations from the common level of our species; and since I am going soon to speak of the significance of individual variation, I cannot introduce that subject better than by calling to remembrance the line of pioneers in chemistry, in physics, and in engineering, by the working of whose rare—or, if you will, abnormal—intellects a meeting of the British Association on this side of the globe has been made physically possible.

I have next to refer to the loss within the year of Sir David Gill, a former President of this Association, himself one of the outstanding great. His greatness lay in the power of making big foundations. He built up the Cape Observatory; he organised international geodesy; he conceived and carried through the plans for the photography of the whole sky, a work in which Australia is bearing a conspicuous part.

[1] Delivered in Melbourne on Friday, August 14, 1914.

Astronomical observation is now organised on an international scale, and of this great scheme Gill was the heart and soul. His labours have ensured a base from which others will proceed to discovery otherwise impossible. His name will be long remembered with veneration and gratitude.

As the subject of the Addresses which I am to deliver here and in Sydney I take *Heredity*. I shall attempt to give the essence of the discoveries made by Mendelian or analytical methods of study, and I shall ask you to contemplate the deductions which these physiological facts suggest in application both to evolutionary theory at large and to the special case of the natural history of human society.

Recognition of the significance of heredity is modern. The term itself in its scientific sense is no older than Herbert Spencer. Animals and plants are formed as pieces of living material split from the body of the parent organisms. Their powers and faculties are fixed in their physiological origin. They are the consequence of a genetic process, and yet it is only lately that this genetic process has become the subject of systematic research and experiment. The curiosity of naturalists has of course always been attracted to such problems; but that accurate knowledge of genetics is of paramount importance in any attempt to understand the nature of living things has only been realised quite lately even by naturalists, and with casual exceptions the laity still know nothing of the matter. Historians debate the past of the human species, and statesmen order its present or profess to guide its future as if the animal Man, the unit of their calculations, with his vast diversity of powers, were a homogeneous material, which can be multiplied like shot.

The reason for this neglect lies in ignorance and misunderstanding of the nature of Variation; for not until the fact of congenital diversity is grasped, with all that it imports, does knowledge of the system of hereditary transmission stand out as a primary necessity in the construction of any theory of Evolution, or any scheme of human polity.

The first full perception of the significance of variation we owe to Darwin. The present generation of evolutionists realises perhaps more fully than did the scientific world in the last century that the theory of Evolution had occupied the thoughts of many and found acceptance with not a few before ever the 'Origin' appeared. We have come also to the conviction that the principle of Natural Selection cannot have been the chief factor in delimiting the species of animals and plants, such as we now with fuller knowledge see them actually to be. We are even more sceptical as to the validity of that appeal to changes in the conditions of life as direct causes of modification, upon which latterly at all events Darwin laid much emphasis. But that he was the

first to provide a body of fact demonstrating the variability of living things, whatever be its causation, can never be questioned.

There are some older collections of evidence, chiefly the work of the French school, especially of Godron[2]—and I would mention also the almost forgotten essay of Wollaston[3]—these however are only fragments in comparison. Darwin regarded variability as a property inherent in living things, and eventually we must consider whether this conception is well founded; but postponing that inquiry for the present, we may declare that with him began a general recognition of variation as a phenomenon widely occurring in Nature.

If a population consists of members which are not alike but differentiated, how will their characteristics be distributed among their offspring? This is the problem which the modern student of heredity sets out to investigate. Formerly it was hoped that by the simple inspection of embryological processes the modes of heredity might be ascertained, the actual mechanism by which the offspring is formed from the body of the parent. In that endeavour a noble pile of evidence has been accumulated. All that can be made visible by existing methods has been seen, but we come little if at all nearer to the central mystery. We see nothing that we can analyse further—nothing that can be translated into terms less inscrutable than the physiological events themselves. Not only does embryology give no direct aid, but the failure of cytology is, so far as I can judge, equally complete. The chromosomes of nearly related creatures may be utterly different both in number, size, and form. Only one piece of evidence encourages the old hope that a connection might be traceable between the visible characteristics of the body and those of the chromosomes. I refer of course to the accessory chromosome, which in many animals distinguishes the spermatozoon about to form a female in *fertilisation. Even it however cannot be claimed as the cause of* sexual differentiation, for it may be paired in forms closely allied to those in which it is unpaired or accessory. The distinction may be present or wanting, like any other secondary sexual character. Indeed, so long as no one can show consistent distinctions between the cytological characters of somatic tissues in the same individual we can scarcely expect to perceive such distinctions between the chromosomes of the various types.

For these methods of attack we now substitute another, less ambitious, perhaps, because less comprehensive, but not less direct. If we cannot see how a fowl by its egg and its sperm gives rise to

[2] *De l'Espèce et des Races dans les Êtres Organisés*, 1859.

[3] *On the Variation of Species*, 1856.

a chicken or how a Sweet Pea from its ovule and its pollen grain produces another Sweet Pea, we at least can watch the system by which the differences between the various kinds of fowls or between the various kinds of Sweet Peas are distributed among the offspring. By thus breaking the main problem up into its parts we give ourselves fresh chances. This analytical study we call Mendelian because Mendel was the first to apply it. To be sure, he did not approach the problem by any such line of reasoning as I have sketched. His object was to determine the genetic definiteness of species; but though in his writings he makes no mention of inheritance it is clear that he had the extension in view. By cross-breeding he combined the characters of varieties in mongrel individuals and set himself to see how these characters would be distributed among the individuals of subsequent generations. Until he began this analysis nothing but the vaguest answers to such a question had been attempted. The existence of any orderly system of descent was never even suspected. In their manifold complexity human characteristics seemed to follow no obvious system, and the fact was taken as a fair sample of the working of heredity.

Misconception was especially brought in by describing descent in terms of 'blood.' The common speech uses expressions such as consanguinity, pure-blooded, half-blood, and the like, which call up a misleading picture to the mind. Blood is in some respects a fluid, and thus it is supposed that this fluid can be both quantitatively and qualitatively diluted with other bloods, just as treacle can be diluted with water. Blood in primitive physiology being the peculiar vehicle of life, at once its essence and its corporeal abode, these ideas of dilution and compounding of characters in the commingling of bloods inevitably suggest that the ingredients of the mixture once combined are inseparable, that they can be brought together in any relative amounts, and in short that in heredity we are concerned mainly with a quantitative problem. Truer notions of genetic physiology are given by the Hebrew expression 'seed.' If we speak of a man as 'of the blood-royal' we think at once of plebeian dilution, and we wonder how much of the royal fluid is likely to be 'in his veins'; but if we say he is 'of the seed of Abraham' we feel something of the permanence and indestructibility of that germ which can be divided and scattered among all nations, but remains recognisable in type and characteristics after 4,000 years.

I knew a breeder who had a chest containing bottles of coloured liquids by which he used to illustrate the relationships of his dogs, pouring from one to another and titrating them quantitatively to illustrate their pedigrees. Galton was beset by the same kind of mistake when he promulgated his 'Law of Ancestral Heredity.' With modern

research all this has been cleared away. The allotment of characteristics among offspring is not accomplished by the exudation of drops of a tincture representing the sum of the characteristics of the parent organism, but by a process of *cell-division*, in which numbers of these characters, or rather the elements upon which they depend, are sorted out among the resulting germ-cells in an orderly fashion. What these elements, or *factors* as we call them, are we do not know. That they are in some way directly transmitted by the material of the ovum and of the spermatozoon is obvious, but it seems to me unlikely that they are in any simple or literal sense material particles. I suspect rather that their properties depend on some phenomenon of arrangement. However that may be, analytical breeding proves that it is according to the distribution of these genetic factors, to use a non-committal term, that the characters of the offspring are decided. The first business of experimental genetics is to determine their number and interactions, and then to make an analysis of the various types of life.

Now the ordinary genealogical trees, such as those which the stud-books provide in the case of the domestic animals, or the Heralds' College provides in the case of man, tell nothing of all this. Such methods of depicting descent cannot even show the one thing they are devised to show—purity of 'blood.' For at last we know the physiological meaning of that expression. An organism is pure-bred when it has been formed by the union in fertilisation of two germ-cells which are alike in the factors they bear; and since the factors for the several characteristics are independent of each other, this question of purity must be separately considered for each of them. A man, for example, may be pure-bred in respect of his musical ability and cross-bred in respect of the colour of his eyes or the shape of his mouth. Though we know nothing of the essential nature of these factors, we know a good deal of their powers. They may confer height, colour, shape, instincts, powers both of mind and body—indeed, so many of the attributes which animals and plants possess, that we feel justified in the expectation that with continued analysis they will be proved to be responsible for most if not all of the differences by which the varying individuals of any species are distinguished from each other. I will not assert that the greater differences which characterise distinct Species are due generally to such independent factors, but that is the conclusion to which the available evidence points. All this is now so well understood, and has been so often demonstrated and expounded, that details of evidence are now superfluous.

But for the benefit of those who are unfamiliar with such work let me briefly epitomise its main features and consequences. Since genetic factors are definite things, either present in or absent from any germ-cell, the individual may be either 'pure-bred' for any particular factor,

or its absence, if he is constituted by the union of two germ-cells both possessing or both destitute of that factor. If the individual is thus pure, all his germ-cells will in that respect be identical, for they are simply bits of the similar germ-cells which united in fertilisation to produce the parent organism. We thus reach the essential principle, that an organism cannot pass on to offspring a factor which it did not itself receive in fertilisation. Parents, therefore, which are both destitute of a given factor can only produce offspring equally destitute of it; and, on the contrary, parents both pure-bred for the presence of a factor produce offspring equally pure-bred for its presence. Whereas the germ-cells of the pure-bred are all alike, those of the cross-bred, which results from the union of dissimilar germ-cells, are mixed in character. Each positive factor segregates from its negative opposite, so that some germ-cells carry the factor and some do not. Once the factors have been identified by their effects, the average composition of the several kinds of families formed from the various matings can be predicted.

Only those who have themselves witnessed the fixed operations of these simple rules can feel their full significance. We come to look behind the simulacrum of the individual body, and we endeavour to disintegrate its features into the genetic elements by whose union the body was formed. Set out in cold general phrases such discoveries may seem remote from ordinary life. Become familiar with them and you will find your outlook on the world has changed. Watch the effects of segregation among the living things with which you have to do—plants, fowls, dogs, horses, that mixed concourse of humanity we call the English race, your friends' children, your own children, yourself—and however firmly imagination be restrained to the bounds of the known and the proved, you will feel something of that range of insight into Nature which Mendelism has begun to give. The question is often asked whether there are not also in operation systems of descent quite other than those contemplated by the Mendelian rules. I myself have expected such discoveries, but hitherto none have been plainly demonstrated. It is true we are often puzzled by the failure of a parental type to reappear in its completeness after a cross—the merino sheep or the fantail pigeon, for example. These exceptions may still be plausibly ascribed to the interference of a multitude of factors, a suggestion not easy to disprove; though it seems to me equally likely that segregation has been in reality imperfect. Of the descent of quantitative characters we still know practically nothing. These and hosts of difficult cases remain almost untouched. In particular the discovery of E. Baur, and the evidence of Winkler in regard to his 'graft hybrids,' both showing that the sub-epidermal layer of a plant—the layer from which the germ-cells are derived—may bear exclusively the characters

of a part only of the soma, give hints of curious complications, and suggest that in plants at least the interrelations between soma and gamete may be far less simple than we have supposed. Nevertheless, speaking generally, we see nothing to indicate that qualitative characters descend, whether in plants or animals, according to systems which are incapable of factorial representation.

The body of evidence accumulated by this method of analysis is now very large, and is still growing fast by the labours of many workers. Progress is also beginning along many novel and curious lines. The details are too technical for inclusion here. Suffice it to say that not only have we proof that segregation affects a vast range of characteristics, but in the course of our analysis phenomena of most unexpected kinds have been encountered. Some of these things twenty years ago must have seemed inconceivable. For example, the two sets of sex organs, male and female, of the same plant may not be carrying the same characteristics; in some animals characteristics, quite independent of sex, may be distributed solely or predominantly to one sex; in certain species the male may be breeding true to its own type, while the female is permanently mongrel, throwing off eggs of a distinct variety in addition to those of its own type; characteristics, essentially independent, may be associated in special combinations which are largely retained in the next generation, so that among the grandchildren there is numerical preponderance of those combinations which existed in the grandparents—a discovery which introduces us to a new phenomenon of polarity in the organism.

We are accustomed to the fact that the fertilised egg has a polarity, a front and hind end for example; but we have now to recognise that it, or the primitive germinal cells formed from it, may have another polarity shown in the groupings of the parental elements. I am entirely sceptical as to the occurrence of segregation solely in the maturation of the germ-cells,[4] preferring at present to regard it as a special case of that patchwork condition we see in so many plants. These mosaics may break up, emitting bud-sports at various cell-divisions, and I suspect that the great regularity seen in the F_2 ratios of the cereals, for example, is a consequence of very late segregation, whereas the excessive irregularity found in other cases may be taken to indicate that segregation can happen at earlier stages of differentiation.

The paradoxical descent of colour-blindness and other sex-limited conditions—formerly regarded as an inscrutable caprice of nature—has been represented with approximate correctness, and we already know something as to the way, or, perhaps, I should say ways, in which the

[4] The fact that in certain plants the male and female organs respectively carry distinct factors may be quoted as almost decisively negativing the suggestion that segregation is confined to the reduction division.

determination of sex is accomplished in some of the forms of life—though, I hasten to add, we have no inkling as to any method by which that determination may be influenced or directed. It is obvious that such discoveries have bearings on most of the problems, whether theoretical or practical, in which animals and plants are concerned. Permanence or change of type, perfection of type, purity or mixture of race, 'racial development,' the succession of forms, from being vague phrases expressing matters of degree, are now seen to be capable of acquiring physiological meanings, already to some extent assigned with precision. For the naturalist—and it is to him that I am especially addressing myself to-day—these things are chiefly significant as relating to the history of organic beings—the theory of Evolution, to use our modern name. They have, as I shall endeavour to show in my second address to be given in Sydney, an immediate reference to the conduct of human society.

I suppose that everyone is familiar in outline with the theory of *the Origin of Species* which Darwin promulgated. Through the last fifty years this theme of the Natural Selection of favoured races has been developed and expounded in writings innumerable. Favoured races certainly can replace others. The argument is sound, but we are doubtful of its value. For us that debate stands adjourned. We go to Darwin for his incomparable collection of facts. We would fain emulate his scholarship, his width and his power of exposition, but to us he speaks no more with philosophical authority. We read his scheme of Evolution as we would that of Lucretius or of Lamarck, delighting in their simplicity and their courage. The practical and experimental study of Variation and Heredity has not merely opened a new field; it has given a new point of view and new standards of criticism. Naturalists may still be found expounding teleological systems[*] which would have delighted Dr. Pangloss himself, but at the present time few are misled. The student of genetics knows that

[*] I take the following from the Abstract of a recent Croonian Lecture 'On the Origin of Mammals' delivered to the Royal Society:—'In Upper Triassic times the larger Cynodonts preyed upon the large Anomodont, *Kannemeyeria*, and carried on their existence so long as these Anomodonts survived, but died out with them about the end of the Trias or in Rhætic times. The small Cynodonts, having neither small Anomodonts nor small Cotylosaurs to feed on, were forced to hunt the very active long-limbed Thecodonts. The greatly increased activity brought about that series of changes which formed the mammals—the flexible skin with hair, the four-chambered heart and warm blood, the loose jaw with teeth for mastication, an increased development of tactile sensation and a great increase of cerebrum. Not improbably the attacks of the newly evolved Cynodont or mammalian type brought about a corresponding evolution in the Pseudosuchian Thecodonts, which ultimately resulted in the formation of Dinosaurs and Birds.' Broom, R., *Proc. Roy. Soc.* B., 87, p. 88.

the time for the development of theory is not yet. He would rather stick to the seed-pan and the incubator.

In face of what we now know of the distribution of variability in nature the scope claimed for Natural Selection in determining the fixity of Species must be greatly reduced. The doctrine of the survival of the fittest is undeniable so long as it is applied to the organism as a whole, but to attempt by this principle to find value in all definiteness of parts and functions, and in the name of Science to see fitness everywhere is mere eighteenth-century optimism. Yet it was in application to the parts, to the details of specific difference, to the spots on the peacock's tail, to the colouring of an Orchid flower, and hosts of such examples, that the potency of Natural Selection was urged with the strongest emphasis. Shorn of these pretensions the doctrine of the survival of favoured races is a truism, helping scarcely at all to account for the diversity of species. Tolerance plays almost as considerable a part. By these admissions almost the last shred of that teleological fustian with which Victorian philosophy loved to clothe the theory of Evolution is destroyed. Those who would proclaim that whatever is is right will be wise henceforth to base this faith frankly on the impregnable rock of superstition, and to abstain from direct appeals to natural fact.

My predecessor said last year that in physics the age is one of rapid progress and profound scepticism. In at least as high a degree this is true of Biology, and as a chief characteristic of modern evolutionary thought we must confess also to a deep but irksome humility in presence of great vital problems. Every theory of Evolution must be such as to accord with the facts of physics and chemistry, a primary necessity to which our predecessors paid small heed. For them the unknown was a rich mine of possibilities on which they could freely draw. For us it is rather an impenetrable mountain out of which the truth can be chipped in rare and isolated fragments. Of the physics and chemistry of life we know next to nothing. Somehow the characters of living things are bound up in properties of colloids, and are largely determined by the chemical powers of enzymes, but the study of these classes of matter has only just begun. Living things are found by a simple experiment to have powers undreamt of, and who knows what may be behind?

Naturally we turn aside from generalities. It is no time to discuss the origin of the Mollusca or of Dicotyledons, while we are not even sure how it came to pass that *Primula obconica* has in twenty-five years produced its abundant new forms almost under our eyes. Knowledge of heredity has so reacted on our conceptions of variation that very competent men are even denying that variation in the old sense is a genuine occurrence at all. Variation is postulated as the basis of all evolutionary change. Do we then as a matter of fact find in the world

about us variations occurring of such a kind as to warrant faith in a contemporary progressive Evolution? Till lately most of us would have said 'yes' without misgiving. We should have pointed, as Darwin did, to the immense range of diversity seen in many wild species, so commonly that the difficulty is to define the types themselves. Still more conclusive seemed the profusion of forms in the various domesticated animals and plants, most of them incapable of existing even for a generation in the wild state, and therefore fixed unquestionably by human selection. These, at least, for certain, are new forms, often distinct enough to pass for species, which has arisen by variation. But when analysis is applied to this mass of variation the matter wears a different aspect. Closely examined, what is the 'variability' of wild species? What is the natural fact which is denoted by the statement that a given species exhibits much variation? Generally one of two things: either that the individuals collected in one locality differ among themselves; or perhaps more often that samples from separate localities differ from each other. As direct evidence of variation it is clearly to the first of these phenomena that we must have recourse—the heterogeneity of a population breeding together in one area. This heterogeneity may be in any degree, ranging from slight differences that systematists would disregard, to a complex variability such as we find in some moths, where there is an abundance of varieties so distinct that many would be classified as specific *forms but for the fact that all* are freely breeding together. Naturalists formerly supposed that any of these varieties might be bred from any of the others. Just as the reader of novels is prepared to find that any kind of parents may have any kind of children in the course of the story, so was the evolutionist ready to believe that any pair of moths might produce any of the varieties included in the species. Genetic analysis has disposed of all these mistakes. We have no longer the smallest doubt that in all these examples the varieties stand in a regular descending order, and that they are simply terms in a series of combinations of factors separately transmitted, of which each may be present or absent.

The appearance of contemporary variability proves to be an illusion. Variation from step to step in the series must occur either by the addition or by the loss of a factor. Now, of the origin of new forms *by loss* there seems to me to be fairly clear evidence, but of the *contemporary acquisition* of any new factor I see no satisfactory proof, though I admit there are rare examples which may be so interpreted. We are left with a picture of variation utterly different from that which we saw at first. Variation now stands out as a definite physiological event. We have done with the notion that Darwin came latterly to favour, that large differences can arise by accumulation of small

differences. Such small differences are often mere ephemeral effects of conditions of life, and as such are not transmissible; but even small differences, when truly genetic, are factorial like the larger ones, and there is not the slightest reason for supposing that they are capable of summation. As to the origin or source of these positive separable factors, we are without any indication or surmise. By their effects we know them to be definite, as definite, say, as the organisms which produce diseases; but how they arise and how they come to take part in the composition of the living creature so that when present they are treated in cell-division as constituents of the germs, we cannot conjecture.

It was a commonplace of evolutionary theory that at least the domestic animals have been developed from a few wild types. Their origin was supposed to present no difficulty. The various races of fowl, for instance, all came from *Gallus bankiva*, the Indian jungle-fowl. So we are taught; but try to reconstruct the steps in their evolution and you realise your hopeless ignorance. To be sure there are breeds, such as Black-red Game and Brown Leghorns, which have the colours of the jungle-fowl, though they differ in shape and other respects. As we know so little as yet of the genetics of shape, let us assume that those transitions could be got over. Suppose, further, as is probable, that the absence of the maternal instinct in the Leghorn is due to loss of one factor which the jungle-fowl possesses. So far we are on fairly safe ground. But how about White Leghorns? Their origin may seem easy to imagine, since white varieties have often arisen in well-authenticated cases. But the white of White Leghorns is not, as white in nature often is, due to the loss of the colour-elements, but to the action of something which inhibits their expression. Whence did that something come? The same question may be asked respecting the heavy breeds, such as Malays or Indian Game. Each of these is a separate introduction from the East. To suppose that these, with their peculiar combs and close feathering, could have been developed from pre-existing European breeds is very difficult. On the other hand, there is no wild species now living any more like them. We may, of course, postulate that there was once such a species, now lost. That is quite conceivable, though the suggestion is purely speculative. I might thus go through the list of domesticated animals and plants of ancient origin and again and again we should be driven to this suggestion, that many of their distinctive characters must have been derived from some wild original now lost. Indeed, to this unsatisfying conclusion almost every careful writer on such subjects is now reduced. If we turn to modern evidence the case looks even worse. The new breeds of domestic animals made in recent times are the carefully selected products of recombination of pre-existing breeds. Most of the

new varieties of cultivated plants are the outcome of deliberate crossing. There is generally no doubt in the matter. We have pretty full histories of these crosses in Gladiolus, Orchids, Cineraria, Begonia, Calceolaria, Pelargonium, &c. A very few certainly arise from a single origin. The Sweet Pea is the clearest case, and there are others which I should name with hesitation. The Cyclamen is one of them, but we know that efforts to cross Cyclamens were made early in the cultural history of the plant, and they may very well have been successful. Several plants for which single origins are alleged, such as the Chinese Primrose, the Dahlia, and Tobacco, came to us in an already domesticated state, and their origins remain altogether mysterious. Formerly single origins were generally presumed, but at the present time numbers of the chief products of domestication, dogs, horses, cattle, sheep, poultry, wheat, oats, rice, plums, cherries, have in turn been accepted as 'polyphyletic,' or, in other words, derived from several distinct forms. The reason that has led to these judgments is that the distinctions between the chief varieties can be traced as far back as the evidence reaches, and that these distinctions are so great, so far transcending anything that we actually know variation capable of effecting, that it seems pleasanter to postpone the difficulty, relegating the critical differentiation to some misty antiquity into which we shall not be asked to penetrate. For it need scarcely be said that this is mere procrastination. If the origin of a form under domestication is hard to imagine, it becomes no easier to conceive of such enormous deviations from type coming to pass in the wild state. Examine any two thoroughly distinct species which meet each other in their distribution, as, for instance, *Lychnis diurna* and *vespertina* do. In areas of overlap are many intermediate forms. These used to be taken to be transitional steps, and the specific distinctness of *vespertina* and *diurna* was on that account questioned. Once it is known that these supposed intergrades are merely mongrels between the two species the transition from one to the other is practically beyond our powers of imagination to conceive. If both these can survive, why has their common parent perished? Why when they cross do they not reconstruct it instead of producing partially sterile hybrids? I take this example to show how entirely the facts were formerly misinterpreted.

When once the idea of a true-breeding—or, as we say, homozygous—type is grasped, the problem of variation becomes an insistent oppression. What can make such a type vary? We know, of course, one way by which novelty can be introduced—by crossing. Cross two well-marked varieties—for instance, of Chinese Primula—each breeding true, and in the second generation by mere recombination of the various factors which the two parental types severally introduced, there will be a profusion of forms, utterly unlike each other, distinct also from

the original parents. Many of these can be bred true, and if found wild would certainly be described as good species. Confronted by the difficulty I have put before you, and contemplating such amazing polymorphism in the second generation from a cross in *Antirrhinum*, Lotsy has lately with great courage suggested to us that all variation may be due to such crossing. I do not disguise my sympathy with this effort. After the blind complacency of conventional evolutionists it is refreshing to meet so frank an acknowledgment of the hardness of the problem. Lotsy's utterance will at least do something to expose the artificiality of systematic zoology and botany. Whatever might or might not be revealed by experimental breeding, it is certain that without such tests we are merely guessing when we profess to distinguish specific limits and to declare that this is a species and that a variety. The only definable unit in classification is the homozygous form which breeds true. When we presume to say that such and such differences are trivial and such others valid, we are commonly embarking on a course for which there is no physiological warrant. Who could have foreseen that the Apple and the Pear—so like each other that their botanical differences are evasive—could not be crossed together, though species of Antirrhinum so totally unlike each other as *majus* and *molle* can be hybridized, as Baur has shown, without a sign of impaired fertility? Jordan was perfectly right. The true-breeding forms which he distinguished in such multitudes are real entities, though the great systematists, dispensing with such laborious analysis, have pooled them into arbitrary Linnean species, for the convenience of collectors and for the simplification of catalogues. Such pragmatical considerations may mean much in the museum, but with them the student of the physiology of variation has nothing to do. These 'little species,' finely cut, true-breeding, and innumerable mongrels between them, are what he finds when he examines any so-called variable type. On analysis the semblance of variability disappears, and the illusion is shown to be due to segregation and recombination of series of factors on pre-determined lines. As soon as the 'little species' are separated out they are found to be fixed. In face of such a result we may well ask with Lotsy, is there such a thing as spontaneous variation anywhere? His answer is that there is not.

Abandoning the attempt to show that positive factors can be added to the original stock, we have further to confess that we cannot often actually prove variation by loss of factor to be a real phenomenon. Lotsy doubts whether even this phenomenon occurs. The sole source of variation, in his view, is crossing. But here I think he is on unsafe ground. When a well-established variety like 'Crimson King' Primula, bred by Messrs. Sutton in thousands of individuals, gives off, as it did a few years since, a salmon-coloured

variety, 'Coral King,' we might claim this as a genuine example of variation by loss. The new variety is a simple recessive. It differs from 'Crimson King' only in one respect, the loss of a single colour-factor, and, of course, bred true from its origin. To account for the appearance of such a new form by any process of crossing is exceedingly difficult. From the nature of the case there can have been no cross since 'Crimson King' was established, and hence the salmon must have been concealed as a recessive from the first origin of that variety, even when it was represented by very few individuals, probably only by a single one. Surely, if any of these had been heterozygous for salmon this recessive could hardly have failed to appear during the process of self-fertilisation by which the stock would be multiplied, even though that selfing may not have been strictly carried out. Examples like this seem to me practically conclusive.[6] They can be challenged, but not, I think, successfully. Then again in regard to those variations in number and division of parts which we call meristic, the reference of these to original cross-breeding is surely barred by the circumstances in *which they often occur.* There remain also the rare examples mentioned already in which a single wild origin may with much confidence be assumed. In spite of repeated trials, no one has yet succeeded in crossing the Sweet Pea with any other leguminous species. We know that early in its cultivated history it produced at least two marked varieties which I can only conceive of as spontaneously arising, though, no doubt, the profusion of forms we now have was made by the crossing of those original varieties. I mention the Sweet Pea thus prominently for another reason, that it introduces us to another though subsidiary form of variation, which may be described as a *fractionation* of factors. Some of my Mendelian colleagues have spoken of genetic factors as permanent and indestructible. Relative permanence in a sense they have, for they commonly come out unchanged after segregation. But I am satisfied that they may occasionally undergo a quantitative disintegration, with the consequence that varieties are produced intermediate between the integral varieties from which they were derived. These disintegrated conditions I have spoken of as subtraction—or reduction—stages. For example, the Picotee Sweet Pea, with its purple edges, can surely be nothing but a condition produced by the factor which ordinarily makes the fully purple flower, quantitatively diminished. The pied animal, such as the Dutch rabbit, must similarly be regarded as the result of partial defect of the chromogen from which the pigment is formed, or conceivably of the factor which effects its oxidation. On such lines I think we may with great confidence

[6] The numerous and most interesting 'mutations' recorded by Professor T. H. Morgan and his colleagues in the fly, *Drosophila*, may also be cited as unexceptionable cases.

interpret all those intergrading forms which breed true and are not produced by factorial interference.

It is to be inferred that these fractional degradations are the consequence of irregularities in segregation. We constantly see irregularities in the ordinary meristic processes, and in the distribution of somatic differentiation. We are familiar with half segments, with imperfect twinning, with leaves partially petaloid, with petals partially sepaloid. All these are evidences of departures from the normal regularity in the rhythms of repetition, or in those waves of differentiation by which the qualities are sorted out among the parts of the body. Similarly, when in segregation the qualities are sorted out among the germ-cells in certain critical cell-divisions, we cannot expect these differentiating divisions to be exempt from the imperfections and irregularities which are found in all the grosser divisions that we can observe. If I am right, we shall find evidence of these irregularities in the association of unconformable numbers with the appearance of the novelties which I have called fractional. In passing let us note how the history of the Sweet Pea belies those ideas of a continuous evolution with which we had formerly to contend. The big varieties came first. The little ones have arisen later, as I suggest by fractionation. Presented with a collection of modern Sweet Peas how prettily would the devotees of Continuity have arranged them in a graduated series, showing how every intergrade could be found, passing from the full colour of the wild Sicilian species in one direction to white, in the other to the deep purple of 'Black Prince,' though happily we know these two to be among the earliest to have appeared.

Having in view these and other considerations which might be developed, I feel no reasonable doubt that though we may have to forgo a claim to variations by addition of factors, yet variation both by loss of factors and by fractionation of factors is a genuine phenomenon of contemporary nature. If then we have to dispense, as seems likely, with any addition from without we must begin seriously to consider whether the course of Evolution can at all reasonably be represented as an unpacking of an original complex which contained within itself the whole range of diversity which living things present. I do not suggest that we should come to a judgment as to what is or is not probable in these respects. As I have said already, this is no time for devising theories of Evolution, and I propound none. But as we have got to recognise that there has been an Evolution, that somehow or other the forms of life have arisen from fewer forms, we may as well see whether we are limited to the old view that evolutionary progress is from the simple to the complex, and whether after all it is conceivable that the process was the other way about. When the facts of genetic discovery become familiarly known to biologists, and cease to be the preoccupa-

tion of a few, as they still are, many and long discussions must inevitably arise on the question, and I offer these remarks to prepare the ground. I ask you simply to open your minds to this possibility. It involves a certain effort. We have to reverse our habitual modes of thought. At first it may seem rank absurdity to suppose that the primordial form or forms of protoplasm could have contained complexity enough to produce the divers types of life. But is it easier to imagine that these powers could have been conveyed by extrinsic additions? Of what nature could these additions be? Additions of material cannot surely be in question. We are told that salts of iron in the soil may turn a pink hydrangea blue. The iron cannot be passed on to the next generation. How can the iron multiply itself? The power to assimilate the iron is all that can be transmitted. A disease-producing organism like the pebrine of silkworms can in a very few cases be passed on through the germ-cells. Such an organism can multiply and can produce its characteristic effects in the next generation. But it does not become part of the invaded host, and we cannot conceive it taking part in the geometrically ordered processes of segregation. These illustrations may seem too gross; but what refinement will meet the requirements of the problem, that the thing introduced must be, as the living organism itself is, capable of multiplication and of subordinating itself in a definite system of segregation? That which is conferred in variation must rather itself be a change, not of material, but of arrangement, or of motion. The invocation of additions extrinsic to the organism does not seriously help us to imagine how the power to change can be conferred, and if it prove that hope in that direction must be abandoned, I think we lose very little. By the re-arrangement of a very moderate number of things we soon reach a number of possibilities practically infinite.

That primordial life may have been of small dimensions need not disturb us. Quantity is of no account in these considerations. Shakespeare once existed as a speck of protoplasm not so big as a small pin's head. To this nothing was added that would not equally well have served to build up a baboon or a rat. Let us consider how far we can get by the process of removal of what we call 'epistatic' factors, in other words those that control, mask, or suppress underlying powers and faculties. I have spoken of the vast range of colours exhibited by modern Sweet Peas. There is no question that these have been derived from the one wild bi-colour form by a process of successive removals. When the vast range of form, size, and flavour to be found among the cultivated apples is considered it seems difficult to suppose that all this variety is hidden in the wild crab-apple. I cannot positively assert that this is so, but I think all familiar with Mendelian analysis would agree with me that it is probable, and that the wild crab contains presumably

inhibiting elements which the cultivated kinds have lost. The legend that the seedlings of cultivated apples become crabs is often repeated. After many inquiries among the raisers of apple seedlings I have never found an authentic case—once only even an alleged case, and this on inquiry proved to be unfounded. I have confidence that the artistic gifts of mankind will prove to be due not to something added to the make-up of an ordinary man, but to the absence of factors which in the normal person inhibit the development of these gifts. They are almost beyond doubt to be looked upon as *releases* of powers normally suppressed. The instrument is there, but it is 'stopped down.' The scents of flowers or fruits, the finely repeated divisions that give its quality to the wool of the Merino, or in an analogous case the multiplicity of quills to the tail of the fantail pigeon, are in all probability other examples of such releases. You may ask what guides us in the discrimination of the positive factors and how we can satisfy ourselves that the appearance of a quality is due to loss. It must be conceded that in these determinations we have as yet recourse only to the effects of dominance. When the tall pea is crossed with the dwarf, since the offspring is tall we say that the tall parent passed a factor into the cross-bred which makes it tall. The pure tall parent had two doses of this factor; the dwarf had none; and since the cross-bred is tall we say that one dose of the dominant tallness is enough to give the full height. The reasoning seems unanswerable. But the commoner result of crossing is the production of a form intermediate between the two pure parental types. In such examples we see clearly enough that the full parental characteristics can only appear when they are homozygous—formed from similar germ-cells, and that one dose is insufficient to produce either effect fully. When this is so we can never be sure which side is positive and which negative. Since, then, when dominance is incomplete we find ourselves in this difficulty, we perceive that the amount of the effect is our only criterion in distinguishing the positive from the negative, and when we return even to the example of the tall and dwarf peas the matter is not so certain as it seemed. Professor Cockerell lately found among thousands of yellow sunflowers one which was partly red. By breeding he raised from this a form wholly red. Evidently the yellow and the wholly red are the pure forms, and the partially red is the heterozygote. We may then say that the yellow is YY with two doses of a positive factor which inhibits the development of pigment; the red is yy, with no dose of the inhibitor; and the partially red are Yy, with only one dose of it. But we might be tempted to think the red was a positive characteristic, and invert the expressions, representing the red as RR, the partly red as Rr, and the yellow as rr. According as we adopt the one or the other system of expression we shall interpret the evolutionary change as one of loss or as one of

addition. May we not interpret the other apparent new dominants in the same way? The white dominant in the fowl or in the Chinese Primula can inhibit colour. But may it not be that the original coloured fowl or Primula had two doses of a factor which inhibited this inhibitor? The Pepper Moth, *Amphidasys betularia*, produced in England about 1840 a black variety, then a novelty, now common in certain areas, which behaves as a full dominant. The pure blacks are no blacker than the cross-bred. Though at first sight it seems that the black *must* have been something added, we can without absurdity suggest that the normal is the term in which two doses of inhibitor are present, and that in the absence of one of them the black appears.

In spite of seeming perversity, therefore, we have to admit that there is no evolutionary change which in the present state of our knowledge we can positively declare to be not due to loss. When this has been conceded it is natural to ask whether the removal of inhibiting factors may not be invoked in alleviation of the necessity which has driven students of the domestic breeds to refer their diversities to multiple origins. Something, no doubt, is to be hoped for in that direction, but not until much better and more extensive knowledge of what variation by loss may effect in the living body can we have any real assurance that this difficulty has been obviated. We should be greatly helped by some indication as to whether the origin of life has been single or multiple. Modern opinion is, perhaps, inclining to the multiple theory, but we have no real evidence. Indeed, the problem still stands outside the range of scientific investigation, and when we hear the spontaneous formation of formaldehyde mentioned as a possible first step in the origin of life, we think of Harry Lauder in the character of a Glasgow schoolboy pulling out his treasures from his pocket—'That's a wassher—for makkin' motor cars'!

As the evidence stands at present all that can be safely added in amplification of the evolutionary creed may be summed up in the statement that variation occurs as a definite event often producing a sensibly discontinuous result; that the succession of varieties comes to pass by the elevation and establishment of sporadic groups of individuals owing their origin to such isolated events; and that the change which we see as a nascent variation is often, perhaps always, one of loss. Modern research lends not the smallest encouragement or sanction to the view that gradual evolution occurs by the transformation of masses of individuals, though that fancy has fixed itself on popular imagination. The isolated events to which variation is due are evidently changes in the germinal tissues, probably in the manner in which they divide. It is likely that the occurrence of these variations is wholly irregular, and as to their causation we are absolutely without surmise or even plausible speculation. Distinct types once arisen, no

doubt a profusion of the forms called species have been derived from them by simple crossing and subsequent recombination. New species may be now in course of creation by this means, but the limits of the process are obviously narrow. On the other hand, we see no changes in progress around us in the contemporary world which we can imagine likely to culminate in the evolution of forms distinct in the larger sense. By intercrossing dogs, jackals, and wolves new forms of these types can be made, some of which may be species, but I see no reason to think that from such material a fox could be bred in indefinite time, or that dogs could be bred from foxes.

Whether Science will hereafter discover that certain groups can by peculiarities in their genetic physiology be declared to have a prerogative quality justifying their recognition as species in the old sense, and that the differences of others are of such a subordinate degree that they may in contrast be termed varieties, further genetic research alone can show. I myself anticipate that such a discovery will be made, but I cannot defend the opinion with positive conviction.

Somewhat reluctantly, and rather from a sense of duty, I have devoted most of this Address to the evolutionary aspects of genetic research. We cannot keep these things out of our heads, though sometimes we wish we could. The outcome, as you will have seen, is negative, destroying much that till lately passed for gospel. Destruction may be useful, but it is a low kind of work. We are just about where Boyle was in the seventeenth century. We can dispose of Alchemy, but we cannot make more than a quasi-chemistry. We are awaiting our Priestley and our Mendeléeff. In truth it is not these wider aspects of genetics that are at present our chief concern. They will come in their time. The great advances of science are made like those of evolution, not by imperceptible mass-improvement, but by the sporadic birth of penetrative genius. The journeymen follow after him, widening and clearing up, as we are doing along the track that Mendel found.

PART II.—SYDNEY.[7]

AT Melbourne I spoke of the new knowledge of the properties of living things which Mendelian analysis has brought us. I indicated how these discoveries are affecting our outlook on that old problem of natural history, the origin and nature of Species, and the chief conclusion I drew was the negative one, that, though we must hold to our faith in the Evolution of Species, there is little evidence as to how it has come about, and no clear proof that the process is continuing in any considerable degree at the present time. The thought

[7] Delivered in Sydney on Thursday, August 20, 1914.

uppermost in our minds is that knowledge of the nature of life is altogether too slender to warrant speculation on these fundamental subjects. Did we presume to offer such speculations they would have no more value than those which alchemists might have made as to the nature of the elements. But though in regard to these theoretical aspects we must confess to such deep ignorance, enough has been learnt of the general course of heredity within a single species to justify many practical conclusions which cannot in the main be shaken. I propose now to develop some of these conclusions in regard to our own species, Man.

In my former Address I mentioned the condition of certain animals and plants which are what we call 'polymorphic.' Their populations consist of individuals of many types, though they breed freely together with perfect fertility. In cases of this kind which have been sufficiently investigated it has been found that these distinctions—sometimes very great and affecting most diverse features of organisation—are due to the presence or absence of elements, or factors as we call them, which are treated in heredity as separate entities. These factors and their combinations produce the characteristics which we perceive. No individual can acquire a particular characteristic unless the requisite factors entered into the composition of that individual at fertilisation, being received either from the father or from the mother or from both, and consequently no individual can pass on to his offspring positive characters which he does not himself possess. Rules of this kind have already been traced in operation in the human species; and though I admit that an assumption of some magnitude is involved when we extend the application of the same system to human characteristics in general, yet the assumption is one which I believe we are fully justified in making. With little hesitation we can now declare that the potentialities and aptitudes, physical as well as mental, sex, colours, powers of work or invention, liability to diseases, possible duration of life, and the other features by which the members of a mixed population differ from each other, are determined from the moment of fertilisation; and by all that we know of heredity in the forms of life with which we can experiment we are compelled to believe that these qualities are in the main distributed on a factorial system. By changes in the outward conditions of life the expression of some of these powers and features may be excited or restrained. For the development of some an external opportunity is needed, and if that be withheld the character is never seen, any more than if the body be starved can the full height be attained; but such influences are superficial and do not alter the genetic constitution.

The factors which the individual receives from his parents and no others are those which he can transmit to his offspring; and if a factor

was received from one parent only, not more than half the offspring, on an average, will inherit it. What is it that has so long prevented mankind from discovering such simple facts? Primarily the circumstance that as man must have *two* parents it is not possible quite easily to detect the contributions of each. The individual body is a *double* structure, whereas the germ-cells are *single*. Two germ-cells unite to produce each individual body, and the ingredients they respectively contribute interact in ways that leave the ultimate product a medley in which it is difficult to identify the several ingredients. When, however, their effects are conspicuous the task is by no means impossible. In part also even physiologists have been blinded by the survival of ancient and obscurantist conceptions of the nature of man by which they were discouraged from the application of any rigorous analysis. Medical literature still abounds with traces of these archaisms, and, indeed, it is only quite recently that prominent horse-breeders have come to see that the dam matters as much as the sire. For them, though vast pecuniary considerations were involved, the old 'homunculus' theory was good enough. We were amazed at the notions of genetic physiology which Professor Baldwin Spencer encountered in his wonderful researches among the natives of Central Australia; but in truth, if we reflect that these problems have engaged the attention of civilised man for ages, the fact that he, with all his powers of recording and deduction, failed to discover any part of the Mendelian system is almost as amazing. The popular notion that any parents can have any kind of children within the racial limits is contrary to all experience, yet we have gravely entertained such ideas. As I have said elsewhere, the truth might have been found out at any period in the world's history if only pedigrees had been drawn the right way up. If, instead of exhibiting the successive pairs of progenitors who have contributed to the making of an ultimate individual, some one had had the idea of setting out the posterity of a single ancestor who possessed a marked feature such as the Habsburg lip, and showing the transmission of this feature along some of the descending branches and the permanent loss of the feature in collaterals, the essential truth that heredity can be expressed in terms of presence and absence must have at once become apparent. For the descendant is not, as he appears in the conventional pedigree, a sort of pool into which each tributary ancestral stream has poured something, but rather a conglomerate of ingredient-characters taken from his progenitors in such a way that some ingredients are represented and others are omitted.

Let me not, however, give the impression that the unravelling of such descents is easy. Even with fairly full details, which in the case of man are very rarely to be had, many complications occur, often preventing us from obtaining more than a rough general indication of

the system of descent. The nature of these complications we partly understand from our experience of animals and plants which are amenable to breeding under careful restrictions, and we know that they are mostly referable to various effects of interaction between factors by which the presence of some is masked.

Necessarily the clearest evidence of regularity in the inheritance of human characteristics has been obtained in regard to the descent of marked abnormalities of structure and congenital diseases. Of the descent of ordinary distinctions such as are met with in the normal healthy population we know little for certain. Hurst's evidence, that two parents both with light-coloured eyes—in the strict sense, meaning that no pigment is present on the front of the iris—do not have dark-eyed children, still stands almost alone in this respect. With regard to the inheritance of other colour-characteristics some advance has been made, but everything points to the inference that the genetics of colour and many other features in man will prove exceptionally complex. There are, however, plenty of indications of system comparable with those which we trace in various animals and plants, and we are assured that to extend and clarify such evidence is only a matter of careful analysis. For the present, in asserting almost any general rules for human descent, we do right to make large reservations for possible exceptions. It is tantalising to have to wait, but of the ultimate result there can be no doubt.

I spoke of complications. Two of these are worth illustrating here, for probably both of them play a great part in human genetics. It was discovered by Nilsson-Ehle, in the course of experiments with certain wheats, that several factors having the same power may co-exist in the same individual. These cumulative factors do not necessarily produce a cumulative effect, for any one of them may suffice to give the full result. Just as the pure-bred tall pea with its two factors for tallness is no taller than the cross-bred with a single factor, so these wheats with three pairs of factors for red colour are no redder than the ordinary reds of the same family. Similar observations have been made by East and others. In some cases, as in the Primulas studied by Gregory, the effect is cumulative. These results have been used with plausibility by Davenport and the American workers to elucidate the curious case of the mulatto. If the descent of colour in the cross between the negro and the white man followed the simplest rule, the offspring of two first-cross mulattos would be, on an average, one black: two mulattos: one white, but this is notoriously not so. Evidence of some segregation is fairly clear, and the deficiency of real whites may perhaps be accounted for on the hypothesis of cumulative factors, though by the nature of the case strict proof is not to be had. But at present I own to a preference for regarding such examples as

instances of imperfect segregation. The series of germ-cells produced by the cross-bred consists of some with no black, some with full black, and others with intermediate quantities of black. No statistical tests of the condition of the gametes in such cases exist, and it is likely that by choosing suitable crosses all sorts of conditions may be found, ranging from the simplest case of total segregation, in which there are only two forms of gametes, up to those in which there are all intermediates in various proportions. This at least is what general experience of hybrid products leads me to anticipate. Segregation is somehow effected by the rhythms of cell-division, if such an expression may be permitted. In some cases the whole factor is so easily separated that it is swept out at once; in others it is so intermixed that gametes of all degrees of purity may result. That is admittedly a crude metaphor, but as yet we cannot substitute a better. Be all this as it may, there are many signs that in human heredity phenomena of this kind are common, whether they indicate a multiplicity of cumulative factors or imperfections in segregation. Such phenomena, however, in no way detract from the essential truths that segregation occurs, and that the organism cannot pass on a factor which it has not itself received.

In human heredity we have found some examples, and I believe that we shall find many more, in which the descent of factors is limited by sex. The classical instances are those of colour-blindness and hæmophilia. Both these conditions occur with much greater frequency in males than in females. Of colour-blindness at least we know that the *sons* of the colour-blind man do not inherit it (unless the mother is a transmitter) and do not transmit it to their children of either sex. Some, probably all, of the daughters of the colour-blind father inherit the character, and though not themselves colour-blind, they transmit it to some (probably, on an average, half) of their offspring of both sexes. For since these normal-sighted women have only received the colour-blindness from one side of their parentage, only half their offspring, on an average, can inherit it. The sons who inherit the colour-blindness will be colour-blind, and the inheriting daughters become themselves again transmitters. Males with normal colour-vision, whatever their own parentage, do not have colour-blind descendants, unless they marry transmitting women. There are points still doubtful in the interpretation, but the critical fact is clear, that the germ-cells of the colour-blind man are of two kinds: (i) those which do not carry on the affection and are destined to take part in the formation of sons; and (ii) those which do carry on the colour-blindness and are destined to form daughters. There is evidence that the ova also are similarly predestined to form one or other of the sexes, but to discuss the whole question of sex-determination is beyond my present scope. The descent of these sex-limited affections never-

theless calls for mention here, because it is an admirable illustration of factorial predestination. It moreover exemplifies that *parental polarity* of the zygote to which I alluded in my first Address, a phenomenon which we suspect to be at the bottom of various anomalies of heredity, and suggests that there may be truth in the popular notion that in some respects sons resemble their mothers and daughters their fathers.

As to the descent of hereditary diseases and malformations, however, we have abundant data for deciding that many are transmitted as dominants and a few as recessives. The most remarkable collection of these data is to be found in family histories of diseases of the eye. Neurology and dermatology have also contributed many very instructive pedigrees. In great measure the ophthalmological material was collected by Edward Nettleship, for whose death we so lately grieved. After retiring from practice as an oculist he devoted several years to this most laborious task. He was not content with hearsay evidence, but travelled incessantly, personally examining all accessible members of the families concerned, working in such a way that his pedigrees are models of orderly observation and recording. His zeal stimulated many younger men to take part in the work, and it will now go on, with the result that the systems of descent of all the common hereditary diseases of the eye will soon be known with approximate accuracy.

Give a little imagination to considering the chief deduction from this work. Technical details apart, and granting that we cannot wholly interpret the numerical results, sometimes noticeably more and sometimes fewer descendants of these patients being affected than Mendelian formulæ would indicate, the expectation is that in the case of many diseases of the eye a large proportion of the children, grand-children, and remoter descendants of the patients will be affected with the disease. Sometimes it is only defective sight that is transmitted; in other cases it is blindness, either from birth or coming on at some later age. The most striking example perhaps is that of a form of night-blindness still prevalent in a district near Montpellier, which has affected at least 130 persons, all descending from a single affected individual [8] who came into the country in the seventeenth century. The transmission is in every case through an affected parent, and no normal has been known to pass on the condition. Such an example well serves to illustrate the fixity of the rules of descent. Similar instances might be recited relating to a great variety of other conditions, some trivial, others grave.

[8] The first human descent proved to follow Mendelian rules was that of a serious malformation of the hand studied by Farabee in America. Drinkwater subsequently worked out pedigrees for the same malformation in England. After many attempts, he now tells me that he has succeeded in proving that the American family and one of his own had an abnormal ancestor in common, five generations ago.

At various times it has been declared that men are born equal, and that the inequality is brought about by unequal opportunities. Acquaintance with the pedigrees of disease soon shows the fatuity of such fancies. The same conclusion, we may be sure, would result from the true representation of the descent of any human faculty. Never since Galton's publications can the matter have been in any doubt. At the time he began to study family histories even the broad significance of heredity was frequently denied, and resemblances to parents or ancestors were looked on as interesting curiosities. Inveighing against hereditary political institutions, Tom Paine remarks that the idea is as absurd as that of an 'hereditary wise man,' or an 'hereditary mathematician,' and to this day I suppose many people are not aware that he is saying anything more than commonly foolish. We, on the contrary, would feel it something of a puzzle if two parents, both mathematically gifted, had any children *not* mathematicians. Galton first demonstrated the overwhelming importance of these considerations, and had he not been misled, partly by the theory of pangenesis, but more by his mathematical instincts and training, which prompted him to apply statistical treatment rather than qualitative analysis, he might, not improbably, have discovered the essential facts of Mendelism.

It happens rarely that science has anything to offer to the common stock of ideas at once so comprehensive and so simple that the courses of our thoughts are changed. Contributions to the material progress of mankind are comparatively frequent. They result at once in application. Transit is quickened; communication is made easier; the food-supply is increased and population multiplied. By direct application to the breeding of animals and plants such results must even flow from Mendel's work. But I imagine the greatest practical change likely to ensue from modern genetic discovery will be a quickening of interest in the true nature of man and in the biology of races. I have spoken cautiously as to the evidence for the operation of any simple Mendelian system in the descent of human faculty; yet the certainty that systems which differ from the simpler schemes only in degree of complexity are at work in the distribution of characters among the human population cannot fail to influence our conceptions of life and of ethics, leading perhaps ultimately to modification of social usage. That change cannot but be in the main one of simplification. The eighteenth century made great pretence of a return to nature, but it did not occur to those philosophers first to inquire what nature is; and perhaps not even the patristic writings contain fantasies much further from physiological truth than those which the rationalists of the 'Encyclopædia' adopted as the basis of their social schemes. For men are so far from being born equal or similar that to the naturalist

they stand as the very type of a polymorphic species. Even most of our local races consist of many distinct strains and individual types. From the population of any ordinary English town as many distinct human breeds could in a few generations be isolated as there are now breeds of dogs, and indeed such a population in its present state is much what the dogs of Europe would be in ten years' time but for the interference of the fanciers. Even as at present constituted, owing to the isolating effects of instinct, fashion, occupation, and social class, many incipient strains already exist.

In one respect civilised man differs from all other species of animal or plant in that, having prodigious and ever-increasing power over nature, he invokes these powers for the preservation and maintenance of many of the inferior and all the defective members of his species. The inferior freely multiply, and the defective, if their defects be not so grave as to lead to their detention in prisons or asylums, multiply also without restraint. Heredity being strict in its action, the consequences are in civilised countries much what they would be in the kennels of the dog-breeder who continued to preserve all his puppies, good and bad: the proportion of defectives increases. The increase is so considerable that outside every great city there is a smaller town inhabited by defectives and those who wait on them. Round London we have a ring of such towns with some 30,000 inhabitants, of whom about 28,000 are defective, largely, though of course by no means entirely, bred from previous generations of defectives. Now, it is not for us to consider practical measures. As men of science we observe natural events and deduce conclusions from them. I may perhaps be allowed to say that the remedies proposed in America, in so far as they aim at the eugenic regulation of marriage on a comprehensive scale, strike me as devised without regard to the needs either of individuals or of a modern State. Undoubtedly if they decide to breed their population of one uniform puritan grey, they can do it in a few generations; but I doubt if timid respectability will make a nation happy, and I am sure that qualities of a different sort are needed if it is to compete with more vigorous and more varied communities. Everyone must have a preliminary sympathy with the aims of eugenists both abroad and at home. Their efforts at the least are doing something to discover and spread truth as to the physiological structure of society. The spirit of such organisations, however, almost of necessity suffers from a bias towards the accepted and the ordinary, and if they had power it would go hard with many ingredients of Society that could be ill-spared. I notice an ominous passage in which even Galton, the founder of eugenics, feeling perhaps some twinge of his Quaker ancestry, remarks that 'as the Bohemianism in the nature of our race is destined to perish, the sooner it goes, the happier for

mankind.' It is not the eugenists who will give us what Plato has called divine releases from the common ways. If some fancier with the catholicity of Shakespeare would take us in hand, well and good; but I would not trust even Shakespeares meeting as a committee. Let us remember that Beethoven's father was an habitual drunkard and that his mother died of consumption. From the genealogy of the patriarchs also we learn—what may very well be the truth—that the fathers of such as dwell in tents, and of all such as handle the harp or organ, and the instructor of every artificer in brass and iron—the founders, that is to say, of the arts and the sciences—came in direct descent from Cain, and not in the posterity of the irreproachable Seth, who is to us, as he probably was also in the narrow circle of his own contemporaries, what naturalists call a *nomen nudum.*

Genetic research will make it possible for a nation to elect by what sort of beings it will be represented not very many generations hence, much as a farmer can decide whether his byres shall be full of shorthorns or Herefords. It will be very surprising indeed if some nation does not make trial of this new power. They may make awful mistakes, but I think they will try.

Whether we like it or not, extraordinary and far-reaching changes in public opinion are coming to pass. Man is just beginning to know himself for what he is—a rather long-lived animal, with great powers of enjoyment if he does not deliberately forgo them. Hitherto superstition and mythical ideas of sin have predominantly controlled these powers. Mysticism will not die out: for those strange fancies knowledge is no cure; but their forms may change, and mysticism as a force for the suppression of joy is happily losing its hold on the modern world. As in the decay of earlier religions Ushabti dolls were substituted for human victims, so telepathy, necromancy, and other harmless toys take the place of eschatology and the inculcation of a ferocious moral code. Among the civilised races of Europe we are witnessing an emancipation from traditional control in thought, in art, and in conduct which is likely to have prolonged and wonderful influences. Returning to freer or, if you will, simpler conceptions of life and death, the coming generations are determined to get more out of this world than their forefathers did. Is it then to be supposed that when science puts into their hand means for the alleviation of suffering immeasurable, and for making this world a happier place, that they will demur to using those powers? The intenser struggle *between communities is only now beginning, and with the approaching* exhaustion of that capital of energy stored in the earth before man began it must soon become still more fierce. In England some of our great-grandchildren will see the end of the easily accessible coal, and, failing some miraculous discovery of available energy, a wholesale

reduction in population. There are races who have shown themselves able at a word to throw off all tradition and take into their service every power that science has yet offered them. Can we expect that they, when they see how to rid themselves of the ever-increasing weight of a defective population, will hesitate? The time cannot be far distant when both individuals and communities will begin to think in terms of biological fact, and it behoves those who lead scientific thought carefully to consider whither action should lead. At present I ask you merely to observe the facts. The powers of science to preserve the defective are now enormous. Every year these powers increase. This course of action must reach a limit. To the deliberate intervention of civilisation for the preservation of inferior strains there must sooner or later come an end, and before long nations will realise the responsibility they have assumed in multiplying these 'cankers of a calm world and a long peace.'

The definitely feeble-minded we may with propriety restrain, as we are beginning to do even in England, and we may safely prevent unions in which both parties are defective, for the evidence shows that as a rule such marriages, though often prolific, commonly produce no normal children at all. The union of such social vermin we should no more permit than we would allow parasites to breed on our own bodies. Further than that in restraint of marriage we ought not to go, at least not yet. Something too may be done by a reform of medical ethics. Medical students are taught that it is their duty to prolong life at whatever cost in suffering. This may have been right when diagnosis was uncertain and interference usually of small effect; but deliberately to interfere now for the preservation of an infant so gravely diseased that it can never be happy or come to any good is very like wanton cruelty. In private few men defend such interference. Most who have seen these cases lingering on agree that the system is deplorable, but ask where can any line be drawn. The biologist would reply that in all ages such decisions have been made by civilised communities with fair success both in regard to crime and in the closely analogous case of lunacy. The real reason why these things are done is because the world collectively cherishes occult views of the nature of life, because the facts are realised by few, and because between the legal mind—to which society has become accustomed to defer—and the seeing eye, there is such physiological antithesis that hardly can they be combined in the same body. So soon as scientific knowledge becomes common property, views more reasonable and, I may add, more humane, are likely to prevail.

To all these great biological problems that modern society must sooner or later face there are many aspects besides the obvious ones. Infant mortality we are asked to lament without the slightest thought

of what the world would be like if the majority of these infants were to survive. The decline in the birth-rate in countries already over-populated is often deplored, and we are told that a nation in which population is not rapidly increasing must be in a decline. The slightest acquaintance with biology, or even school-boy natural history, shows that this inference may be entirely wrong, and that before such a question can be decided in one way or the other, hosts of considerations must be taken into account. In normal stable conditions population is stationary. The laity never appreciates, what is so clear to a biologist, that the last century and a quarter, corresponding with the great rise in population, has been an altogether exceptional period. To our species this period has been what its early years in Australia were to the rabbit. The exploitation of energy-capital of the earth in coal, development of the new countries, and the consequent pouring of food into Europe, the application of antiseptics, these are the things that have enabled the human population to increase. I do not doubt that if population were more evenly spread over the earth it might increase very much more; but the essential fact is that under any stable conditions a limit must be reached. A pair of wrens will bring off a dozen young every year, but each year you will find the same number of pears in your garden. In England the limit beyond which under present conditions of distribution increase of population is a source of suffering rather than of happiness has been reached already. Younger communities living in territories largely vacant are very probably right in desiring and encouraging more population. Increase may, for some temporary reason, be essential to their prosperity. But those who live, as I do, among thousands of creatures in a state of semi-starvation will realise that too few is better than too many, and will acknowledge the wisdom of Ecclesiasticus who said 'Desire not a multitude of unprofitable children.'

But at least it is often urged that the decline in the birth-rate of the intelligent and successful sections of the population—I am speaking of the older communities—is to be regretted. Even this cannot be granted without qualification. As the biologist knows, differentiation is indispensable to progress. If population were homogeneous civilisation would stop. In every army the officers must be comparatively few. Consequently, if the upper strata of the community produce more children than will recruit their numbers some must fall into the lower strata and increase the pressure there. Statisticians tell us that an average of four children under present conditions is sufficient to keep the number constant, and as the expectation of life is steadily improving we may perhaps contemplate some diminution of that number without alarm.

TABLE III.

95 *Errors of P for Milne Seismographs in* 1913.

Error	0° — 40°	40° — 80°	80° — 90°	90° — 100°	100° — 130°	130°
Large Positive	—	+18·7	+39·4	+40·7	—	—
	—	+15·3	—	+25·0	—	—
Transferred to S	—	(6)	(5)	(10)	(5)	—
PR₁	—	+4·3	—	(9)	(6)	—
	—	+3·3	—	—	—	—
Doubtful	—	+2·9	—	+2·8	+2·0	—
	—	+2·7	—	+2·0	—	—
	—	+1·8	—	+1·4	—	—
	—	+1·4	—	—	—	—
	—	+1·2	—	—	—	—
m.						
+0·9	—	1	—	—	1	—
+0·8	—	1	—	—	—	—
+0·7	—	—	1	—	—	—
+0·6	—	—	1	—	1	—
+0·5	1	1	—	—	—	—
+0·4	—	1	—	—	—	—
+0·3	1	3	—	—	—	—
+0·2	—	2	—	—	—	—
+0·1	—	2	—	—	—	—
0·0	—	1	—	—	—	—
−0·1	—	—	—	—	—	—
−0·2	2	1	1	—	—	—
−0·3	—	1	—	—	—	—
−0·4	—	—	—	—	—	—
−0·5	—	—	—	—	—	—
−0·6	—	—	—	—	—	—
−0·7	—	1	—	—	—	—
−0·8	—	—	—	—	—	—
−0·9	—	1	—	1	—	—
Doubtful	−1·2	−1·0	—	−1·9	−1·0	—
	—	−1·2	—	—	—	—
Large Negative	—	− 3·4	—	−5·4	−12·4	—
	—	− 5·8	—	—	−17·5	—
	—	−10·1	—	—	−25·4	—
	—	−35·3	—	—	—	—

all those marked doubtful) only 39, can be regarded as true readings of P; say 40 per cent. at most. With the other machines there are 87 out of 134, or 65 per cent.

Coming now to S, and correcting the results (which include those transferred from P) as for other instruments, we find 12 large errors; the others are distributed as below:—

TABLE IV.

38 Errors for S in Milne Seismographs in 1913.

	Distance from Epicentre 0° — 40°	— 80°	— 130°	All
m. m.				
+3·3 to +3·7	—	1	1	2
+2·8 to +3·2	—	—	—	—
+2·3 to +2·7	—	—	3	3
+1·8 to +2·2	—	1	1	2
+1·3 to +1·7	—	—	1	1
+0·8 to +1·2	—	1	2	3
+0·3 to +0·7	2	2	2	6
−0·2 to +0·2	—	3	3	6
−0·7 to −0·3	—	2	5	7
−1·2 to −0·8	—	—	2	2
−1·7 to −1·3	—	2	2	4
−2·2 to −1·8	—	—	1	1
−2·7 to −2·3	—	1	—	1

The mean of the errors is ± 1·1 m.; for other instruments it was ± 0·73 m. The ratio of these is about the same as in the case of P. But it will be seen that there are acceptable readings of S in 38 cases, whereas for the same earthquakes there are only 39 of P at most. It is usually considered that the Milne instruments show P but not S. The evidence here tabulated points to the conclusion that S is shown at least as well as P. It is true that the five earthquakes considered are large ones; but it might reasonably be argued that P should therefore have the better chance of asserting itself. It seems probable that in some cases P could be recovered from the records when it was realised that the reading formerly given was that of S. The important point is that without any great difficulty it can be settled when we have an S reading, for the cases of doubt are few. We may now give the 12 large errors excluded as mistakes; they are +35·2 m., +11·9 m., +10·3 m., +9·1 m., +8·7 m., +8·6 m., the smallest of which exceeds the maximum error (+3·5 m.) accepted as S by over 5 m.; and on the negative side we have −4·4 m., −4·4 m., −5·1 m., −8·0 m., +11·8 m., and −14·2 m. Here the separation is not so marked; but there is a full 2 m. interval. Some or all of these negative errors may be readings of PR_1, but the two largest, which both occur on January 11 (Toronto −11·8 m. and Stonyhurst −14·2 m.), are supported by several other readings and probably refer to a preliminary shock. As the performance of the Milne pendulums is the main point under

investigation, not only were the above five earthquakes used, but also five others in 1911 as follows:—

—	Date	Adopted Epicentre	Adopted Time		
		° °	h.	m.	s.
I.	1911, July 4	39·0 N., 71·4 E.	13	33	33
II.	1911, July 12	27·0 N., 116·0 E.	4	9	7
III.	1911, Aug. 16	19·0 S., 140·0 E.	22	38	51
IV.	1911, Oct. 14	33·5 N., 82·5 E.	23	24	1
V.	1911, Dec. 16	12·0 N., 101·8 W.	19	13	51

For these earthquakes Pulkovo epicentre determinations were not available, but the results from Galitzin instruments at Eskdalemuir are published in the 'Geophysical Journal,' and have been adopted for use. The computations were kindly made by Mr. A. E. Young, formerly Deputy Surveyor-General of the Malay Survey, who is at present working at the Oxford University Observatory; and in this instance greater care was taken, Mr. Young calculating the distances trigonometrically (instead of reading them from a globe) and using the times and tables to seconds of time in the computations, though in giving the results the unit 0·1m. has been considered sufficient.

V.—*Comparison of Films for* 1911.

The chief object in using this additional material was as follows. It was thought that some of the errors of the Milne instruments might be due to faulty readings of the records, susceptible of correction. To test the general accuracy of such readings the different stations were invited to send their films for the year 1911 to Shide, and many of them have responded. Some had bound up their films in such a way that transmission was undesirable; but films for 1911 have been received at Shide from Cape Town, Cork, Toronto, San Fernando, Sydney, Helwan (Egypt), Victoria, Ascension, Perth, Seychelles, Eskdale, Guildford, and Colombo, and have been systematically examined at Shide by Mr. Burgess and Mr. Pring, who have had much experience in reading the Shide films. It was thought advisable to make this examination quite independently, before knowing whether the revised readings would suit the calculated facts better; and indeed the calculations were made at Oxford, so that the Shide readings were made in ignorance of the tabular result either before or after. On comparing the old and new readings with expectation, it does not appear that the new afford any systematic improvement on the old. The actual figures for the above five earthquakes are as follows (the quantities given being differences from expectation, calculated as already indicated). They apply entirely to the phase P, the phase S being seldom read from the Milne records.

TABLE V.

Comparison of Original and Revised Readings of Various Films for the Phase P.

Ascension.

Quake.	Orig.	Rev.
II.	−5·5	Not read
III.	+5·1	+5·1

Cape Town

I.	−0·9	+0·2
II.	+2·3	+2·9
III.	+6·3	+5·8
V.	+5·5	+5·1

Helwan.

Readings for Jan. and Feb. confirmed former results so consistently that the scrutiny was discontinued as superfluous.

Perth.

III.	+3·5	+3·5
V.	+2·4	+2·5

San Fernando.

I.	−0·2	−3·0
III.	+5·9	+6·0
IV.	+6·5	+21·7
V.	−0·3	−0·7

Seychelles.

Quake.	Orig.	Rev.
I.	+6·0	Not read
II.	+0·0	−1·0
III.	+1·5	+1·5
V.	(37·0)	(34·0)

For V. epicentre is so distant that tables fail.

Sydney.

I.	+2·8	−14·4
II.	−4·5	−41·9
III.	+1·7	−13·2
IV.	+9·6	+ 9·2

For II. an earlier quake is confirmed by Allipore. For III. see Toronto.

Toronto.

I.	+10·1	−14·4
II.	+ 4·9	+ 4·1
III.	+ 9·7	−14·3
V.	− 0·3	− 1·1

For III. see Sydney.

Victoria.

V.	− 0·1	− 0·1

Films not sent for other earthquakes.

After consideration of the above figures, it was decided to apply no corrections at all, but to accept the original readings as they stand, and in Table VI. these are compared with calculated values. The table corresponds to Table III. except that Δ was now used in km., and the grouping is therefore a little different.

There is room for some difference of opinion as to the 17 records marked doubtful; but the 12+13+15+3+4=47 readings in the body of the table are probably normal. We thus get at least 47 but not more than 64 normal readings out of 108. These figures are better than the 1913 figures and encourage the hope that on the whole 50 per cent. of the recorded readings for P may be normal; but the percentage cannot be higher than this.

One feature of the records seems to demand further investigation. There is a suggestion that the readings are divisible into two groups separated by about a whole minute; and this applies also to the results for 1913, though they are scarcely numerous enough to declare it independently. It will be seen that the records −0·4 m. and −0·5 m. are not represented in either table, thus creating an appearance of separation. But this may be purely accidental.

Coming now to S, Table VII. has been formed in the same manner as before, adopting the same corrections to the tables for time of S. There are three consistent observations of S at Δ =15,000 kms. for which the tables are scarcely available but were

TABLE VI.

108 *Errors of P for Milne Seismographs in* 1911.

	Distance from Epicentre in kms. 0 — 5000	— 9000	— 10000	— 11000	— 13000		over
	m.	m.					
Large Errors .	+17·2 —	+22·1 +16·1	— —	— —	— —	— —	
S	(2) — —	(6) — —	(1) — —	(3) — —	(0) — —	— — —	+10·8? + 9·7? + 8·5?
PR_1	— — — —	+4·5 +3·3 +2·6 +2·6	+4·4 +4·3 +4·2 —	+6·1 — — —	+6·3 +5·2 +4·9 —	+5·9 +5·7 +5·5 +5·3	+5·2 +5·1 +4·4 +3·9
Doubtful . .	+1·7 +1·2 +1·0 +1·0	+1·7 +1·7 +1·5 +1·5	+1·5 +1·5 +1·0 —	— — — —	+2·8 +2·3 +1·0 —	+3·0 +2·4 +1·4 —	— — — —
+0·9	—	—	—	—	1	—	
+0·8	—	—	—	—	—	—	
+0·7	—	—	—	—	—	—	
+0·6	1	—	—	—	—	—	
+0·5	—	1	—	—	1	—	
+0·4	—	—	1	—	—	—	
+0·3	—	1	1	—	—	—	
+0·2	1	1	2	—	—	—	
+0·1	—	—	—	—	1	1	
0·0	—	1	1	—	—	—	
−0·1	1	—	2	—	—	1	
−0·2	—	2	—	—	—	—	
−0·3	1	1	2	—	—	1	
−0·4	—	—	—	—	—	—	
−0·5	—	—	—	—	—	—	
−0·6	2	3	—	—	—	—	
−0·7	1	—	—	—	—	—	
−0·8	2	1	2	—	—	—	
−0·9	1	1	2	—	—	—	
−1·0	1	—	—	—	—	—	
−1·1	1	—	—	—	—	—	
−1·2	—	—	1	—	—	—	
−1·3	—	—	1	—	—	—	
−1·4	—	—	—	—	—	—	
−1·5	—	1	—	—	—	—	
Large Errors .	−43·0 — —	−3·6 −4·5 −4·7	−4·8 — —	−3·7 — —	— — —	−5·5 — —	

provisionally extended. It seems clear that an even larger correction is necessary at this distance than has been assumed. In calculating the mean error these observations have been omitted, and the mean error is then $\pm 1{\cdot}1$ m. as before. Including them as they stand raises it to $\pm 1{\cdot}2$ m.

TABLE VII.

36 *Errors for S for Milne Seismographs in* 1911.

	Distance from Epicentre in kms. 0 – 5000	– 9000	– 10000	– 11000	– 16000	– All
+2·8 to +3·2	—	—	1	—	—	1
+2·3 to +2·7	—	1	1	—	—	2
+1·8 to +2·2	1	1	—	—	—	2
+1·3 to +1·7	—	—	—	—	—	0
+0·8 to +1·2	—	—	2	1	—	3
+0·3 to +0·7	—	3	2	1	—	6
−0·2 to +0·2	—	1	3	—	—	4
−0·7 to −0·3	—	3	—	1	—	4
−1·2 to −0·8	4	2	—	1	—	7
−1·7 to −1·3	—	1	1	—	(1)	2
−2·2 to −1·8	—	1	—	—	(2)	1
−2·7 to −2·3	—	1	—	—	—	1

In addition there are three large positive errors (+9·9 m., +7·8 m. and +7·8 m.) and four large negative (−5·2 m., −5·8 m., −6·7 m. and −8·1 m.), which may be reflected waves. The percentage is slightly less than before, but, putting 1911 and 1913 together, we have 36+39=75 tolerably certain S readings as against 47+25=72, or possibly 64+39=103 P readings. The fact that S is as often readable as P on Milne seismograms, at any rate for large earthquakes, seems to be thus fairly well established.

VI.—*Comparison of Milne and Galitzin Instruments.*

To the information conveyed by the above discussion the following may be added. At Eskdalemuir Observatory various seismographs have been mounted side by side for comparison, and Mr. G. W. Walker made very careful and thorough comparisons of the relative advantages as indicated in his book already referred to. It seemed desirable at the present juncture to have a formal report on the comparison of the Milne instrument with at least one other; and the Galitzin seemed the best to select as standard of comparison. Application was therefore made to the Superintendent of the Meteorological Office, and he kindly sent the following report, to which the names of L. F. Richardson and L. H. G. Dines are attached.

Comparison between the Milne and the Galitzin types of Seismographs.

It is convenient to treat the question under several different aspects, and a brief description of the two instruments may usefully precede the rest.

It is unnecessary to say much about the Milne instrument. Extreme lightness and compactness characterise it, and no simpler

method of optical registration could well be devised. No expensive lenses are needed, and, with the exception of a few parts of the mechanism, no specially high-class work is required in manufacture. The whole of the apparatus is self-contained and does not take up much floor-space. It does not require a continuously darkened room in which to work. Two pendulums to record both N.S. and E.W. movements can be installed in the same case and record on the same drum.

The Galitzin instrument, on the other hand, is a very much more complicated affair. It is designed to follow a somewhat elaborate mathematical theory, and high-class workmanship and accuracy are needed in its construction. Its pendulum is shorter than the Milne and much heavier—say, seven kilograms. It is hung by two steel wires (Zollner system), and has no pivot at all in some cases. Provision, however, is made on the pendulum and frame for a steel point and cup to be inserted if required. The supporting wires might, with advantage, be made of tungsten if corrosion were feared. At the outer end of the boom are fixed to the frame four powerful horseshoe magnets. Between the poles of one pair of these moves a set of wire coils fixed to the boom and coupled in series with a delicate galvanometer placed in any convenient position elsewhere. Between the other pair is a large copper plate, also fixed to the boom, and this last acts as a magnetic damper. The magnets can be adjusted as desired to vary the magnetic field between the poles.

The galvanometer is of the moving coil type, and has a long period of oscillation when undamped. This galvanometer is an excellent piece of work and is electrically damped so that it can be rendered just aperiodic. With the whole instrument in normal working it is necessary that the undamped periods of both pendulum and galvanometer should be the same, and that they both should be damped just to the limit of aperiodicity.

The optical registration consists of a collimator with a fine slit powerfully illuminated. The beam is reflected from a mirror on the galvanometer and thence to the recording drum, where a cylindrical lens condenses the line of light into a point on the paper.

The two pendulums for recording N.S. and E.W. movements are under entirely separate covers, and in a more refined installation two separate drums are also used; but it is possible to use one drum only and arrange the spots of light from the two galvanometers side by side.

A good deal of floor space is required, and the room in which the recording parts are placed must be kept dark.

The galvanometers and recording drum may be placed in a separate room altogether; and, in fact, are better so placed. The presence of the attendant is likely to disturb the pendulum if he brings his weight near the pillar on which it stands. The recording part of the apparatus is quite unaffected by disturbances in the room in which it is placed.

For a further description of the Galitzin instrument see (1) 'Modern Seismology,' by G. W. Walker, F.R.S., chapters 2 and 3.

(2) The catalogue supplied by H. Masing, St. Petersburg, the makers of the pendulum and recording part of the instrument. (3) 'Ueber ein neues Aperiodisches Horizontalpendel mit galvanometrischer Fernregistrierung,' by Prince B. Galitzin. (4) 'Ueber einen neuen Seismographen für die Vertikalkomponente der Bodenbewegung,' by Prince B. Galitzin. (5) 'Die electromagnetische Registriermethode,' by Prince B. Galitzin, Academy of Sciences, St. Petersburg.

The Galitzin recorder for vertical movements operates electrically in exactly the same manner as the horizontal instrument, and a similar magnetic damper is fitted to it. The room in which the pendulum is placed must be maintained as far as possible at a uniform temperature, as the change in the elasticity of the spring which supports the pendulum causes excessive wandering if the temperature changes by even as little as 0.5 per cent.

Comparative cost.—A Galitzin installation is much more expensive than a corresponding Milne one. Two horizontal pendulums complete with galvanometer and one recording drum cost at least 148*l.*, while the pendulum for vertical movements with galvanometer and drum costs at least 110*l.*

This does not exhaust the expensiveness of the instruments, since about six times as much sensitive paper is required for one Galitzin recording drum as for one modern Milne drum for two pendulums. It is customary to run the paper at three centimetres per minute, and unless the optical arrangements were improved it would be hardly feasible to run it at much less speed without losing a good deal. Under these circumstances the cost in paper alone of one recorder is about 33*l.* per annum.

Attention required.—The Milne instrument does not require more than ordinary skilled attention. If the operator be used to handling delicate instruments little more is required. Of the Galitzin instrument the same may be said as far as the ordinary routine is concerned, but the greater complexity of the apparatus means a greater number of things liable to go wrong, and sooner or later it is almost certain to happen that highly skilled attention is necessary. Both types of instrument require periodical standardisation, but while in the Milne type this is quite a simple process, in the Galitzin it is quite otherwise. A certain amount of auxiliary apparatus is required, such as telescopes and scales, and two persons are necessary to make simultaneous observations of the pendulum and galvanometer; when these have been made the constants of the instrument can be determined. Prince Galitzin has worked out formulæ for this purpose.

The whole process has in general to be gone through twice for each instrument, and it is a lengthy operation, taking probably about two working days. A certain measure of observational skill is required to take the necessary readings accurately, as well as a fair working knowledge of mathematics to deal with the results when obtained.

It would be possible to simplify the process somewhat more than has at present been done, and reduce it largely to routine; but

a Galitzin installation must always require a greater measure of skilled attention to run it successfully than is the case with the simpler types of instruments.

It is difficult to estimate what is the minimum of mathematical and physical knowledge that must be possessed by an assistant in order to maintain successfully a Galitzin installation. A working knowledge of algebra is essential, and probably with this as a basis an intelligent operator could learn the rest of the routine with the aid of computing-forms. But without a knowledge of higher mathematics, and particularly elementary differential equations, it is impossible to understand the meaning of the formulæ by which the constants are determined.

Results obtainable.—The Milne type of instrument is very sensitive as a mere seismoscope. With the exception of very faint movements indeed, some record of a distant quake can always be obtained by it; this is due to the absence of damping and almost entire absence of solid friction; by altering the period of oscillation of the boom it can be made particularly sensitive to any wave-period desired. The instrument at Eskdalemuir Observatory has at present a period of about eighteen seconds, and this corresponds approximately with the wave periods from very faint and remote shocks. For waves of this type the Milne instrument leaves some record of almost any earthquake that affects the Galitzin instrument; but whereas the latter gives a trace that approximately follows the actual movements of the ground, the trace from the former has little resemblance to it. Maximum movements on the Milne record may or may not coincide with the maximum movements of the ground: it depends on the type of the earth movements and on the period of the pendulum. By damping slightly, a more faithful record can be obtained, and by making the pendulum actually dead beat a moderately close agreement will prevail between the actual earth movements and those worked out from the record. This can be established theoretically, but Prince Galitzin has also conducted experiments which show that theory and practice are in close agreement. See Professor C. G. Knott's book on 'The Physics of Earthquake Phenomena,' chapter 5. Unfortunately the reduction in the scale of the record which accompanies damping renders the Milne pendulum very insensitive when damped. For some months an oil damper has been fitted to one of the Milne pendulums at Eskdalemuir; the ratio of successive elongations is approximately 2:4. The results obtained are disappointing for the reason given above.

If any satisfactory means could be found of increasing the magnification optically even by a moderate amount, the damped Milne pendulum should be capable of yielding good results, and the greater simplicity of standardisation should be another point in its favour.

Turning to the Galitzin type of machine, as an instrument of precision it may safely be said to be ahead of all others. The interpretation of its records is not a very simple matter, but by those prepared to spend the time a vast amount of information can be

obtained. The scale of magnification varies widely with different wave-periods, being in general approximately 800 as a maximum and for periods of about fourteen seconds, and falling off for either longer or shorter periods.

The preliminary tremors of a distant earthquake can be examined particularly well, and individual impulses analysed. An experienced observer can analyse these preliminary phases from the shape and general appearance of the record far more easily than can be done in the case of the undamped Milne record. See 'Modern Seismology,' by G. W. Walker, F.R.S., chapter 7, for fuller information on this point.

It is probably safe to say that a full and rigid investigation into the theory of these instruments has not yet been published, and the possibilities of deducing complicated formulæ in that direction are vast. The high degree of accuracy that in favourable circumstances has been obtained in locating epicentres, using the records from a single station only, is sufficient to demonstrate the excellence of the instrument as at present used. It would be well to state here that, though the Galitzin record does not represent the ground motion accurately in many cases, yet in the case of the first movement of the first phase P of an earthquake the movements on the N.S. and E.W. records will be proportional to the actual earth movements provided that the two pendulums and galvanometers are in correct adjustment and have the same undamped period. Hence the azimuth can in favourable circumstances be accurately and easily determined, though to work out the actual earth movements would be a complicated matter.

One point worthy of mention in which the Galitzin instrument differs from most or perhaps all others is the absence of trouble arising from the wandering of the pendulum. However the latter may wander, the zero of the galvanometer is unaffected. The scale value may be altered slightly if the pendulum be far from the middle position, but this can easily be corrected from time to time. This quality renders the instrument useless for determining slow changes in tilt, as can be done with other types.

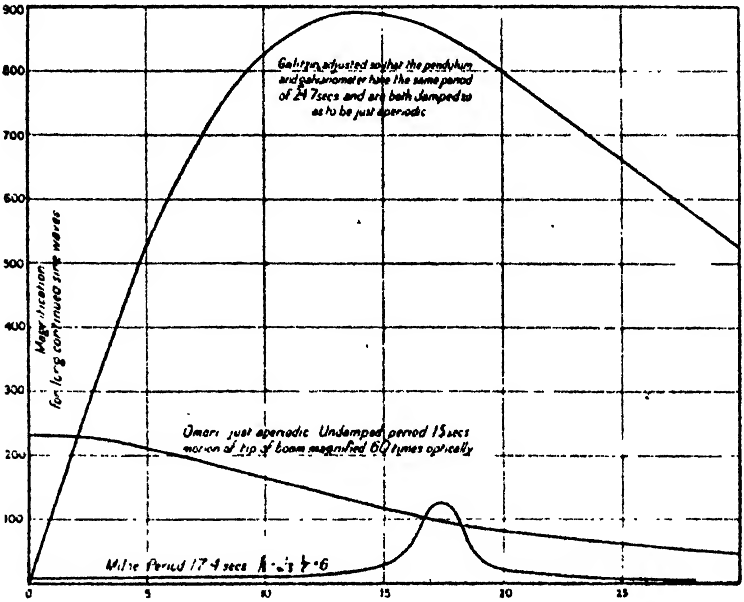
Mention has been made above of varying scale value; this introduces another limitation. For very short periods the magnification is very small, being about 110 for one-second period and varying directly as the period for lesser values.

Hence rapid vibrations will leave no record, and this may be the explanation of the fact that small local earthquakes are not recorded on this type of instrument.

Owing to the high degree of magnification and great sensitivity, some trouble is experienced from disturbances due to high winds, and from experience at Eskdalemuir it would seem desirable to house the pendulum in a small sheltered building rather than a large exposed one. Heavy weights moving in the vicinity cause trouble, as with any other sensitive instruments; but the records so produced being of definite character can be readily traced to their origin, and are immaterial if not

too frequent. Occasional traffic along a neighbouring road would not cause much confusion on the record.

A curve is shown attached giving the magnification of movement in both the Milne and Galitzin types. It refers solely to the case



of a long-continued series of uniform waves; but it is noteworthy that in the Milne type it cannot be applied to any other kind of motion and may be considerably in error even one or two minutes after the commencement of the series.

In the Galitzin type, however, the free motion dies away much more rapidly.

VII.—*Present Value of the Milne Instrument.*

We may summarise the present situation as follows:—

(*a*) The Milne instrument is undamped, but for one purpose—viz., the determination of times of arrival of P and S—this does not matter. There has been an idea that S (or P_2) is not easy to read on Milne records; but S has often been read in mistake for P, and when these readings are counted properly S seems to be identifiable as often as P. On the other hand, the absence of damping makes the readings of maximum of uncertain significance.

(*b*) The time scale of the Milne instrument is small and its magnification is also small. Both might be increased with advantage, and it seems probable that then the times of arrival of P and S could be read as well as on most other instruments.

(*c*) The present wide dispersion of Milne stations makes the records of great value. Most of the modern instruments are in Europe. For

an earthquake in Europe they are distributed in various azimuths (not quite a complete circuit even then), but for distant quakes they cluster in the same azimuth and give no material for discussion in azimuth (see Section VIII.). The Milne stations, however, especially those in Australia, can supply this information.

It is clear, then, that the usefulness of the Milne instruments is by no means at an end, as the perfection of modern seismographs (especially the Galitzin instrument) might at first suggest. And it should not be difficult to extend it considerably.

(*a*) It can be *damped* effectually. Mr. J. J. Shaw, of West Bromwich, has done this electro-magnetically with an aluminium plate in place of the Galitzin copper plate, which is too heavy for the light Milne boom. At present, however, he has not obtained simultaneously sufficient magnification to give the damping effect: damping is chiefly of use for following the movements of the long waves, and the scale should be big enough to show them clearly. Mr. Shaw is still at work on the instrument, and hopes to obtain the requisite magnification.

(*b*) There should be little difficulty in increasing the magnification moderately both in movement and in time scale, though it may not be easy to settle which is the very best way of doing it. The experiments being made by various observers should at least give us a feasible plan.

(*c*) Meanwhile *if special attention is paid to getting good time determinations*, and if the films are carefully read with a lens, the times of arrival of P and S for Milne stations should enable us to correct the tables for considerable distances from the epicentre where the European stations all agree and are all in error owing to their congestion in azimuth. (See next Section.)

VIII.—*Correction of the Tables for P and S.*

Recurring to the discussion of Section IV., it was shown that the tables for both P and S were sensibly in error, and the question arises how far they can be corrected. The main facts are these:—

(α) The tables for small values of Δ are sensibly correct. This is shown by the agreement of determinations of epicentres from Pulkovo and Eskdalemuir, quoted by G. W. Walker in his monograph (p. 65). From each station the azimuth a and the distance Δ can be determined; and from the two azimuths a and a_2 the epicentre can be determined without reference to Δ at all.[1] This is a modern advance, the importance of which is not easily over-estimated. If then the values of Δ determined from the P and S tables agree (to a fraction of a degree) with those found from the azimuths, the tables must be fairly correct. The value of Δ is about 20°.

(β) But this single example may give quite a wrong impression of the accuracy with which an epicentre is at present determined. At greater distances we gradually lose the accordance between these stations. Thus, on January 4, 1912, Pulkovo gives 175° E., 49°·5 N., and Eskdale-

[1] See letter of Galitzin and Walker in *Nature* for September 5, 1912.

muir 177° E., 51° N.; on July 9 Pulkovo gives 30°·3 E., 2°·1 N., and Eskdalemuir 33°·9 E. and 5°·3 N.; and at greater distances still the discordance may be 5° or even 10°. The azimuths may still be good, though as the azimuthal lines do not meet so sharply, the determination becomes less definite; and, moreover, it must be remembered that actual errors in the adjustment of the booms become of greater importance. We have nothing to set against the clear evidence offered in Section IV. that the tables for S are in error, though since the errors there found are only *relative*, we may add a constant to them all, substituting, for instance, for

Error at	15°	35°	55°	75°	95°	115°
	m.	m.	m.	m.	m.	m.
	−0·3	−0·1	+0·1	+0·3	+0·5	+0·7

the revised values

0·0	+0·2	+0·4	+0·6	+0·8	+1·0

so that the error is small near the epicentre.

Similarly the errors for P might be written—

Error at	15°	35°	55°	75°	95°	115°
	m.	m.	m.	m.	m.	m.
	0·0	0·0	+0·1	+0·2	+0·4	+0·6

if we determine to keep the error small near the epicentre. In this case it seems possible that the revised tables just published by the K.G. Landesantalt für Meteorologie und Geodynamik in Zagreb (Agram) might supply information which would determine the unknown arbitrary constant. The errors of the Galitzin tables indicated by Zagreb at the above points are

	m.	m.	m	m.	m.	m.
	+0·1	+0·1	0·0	+0·1	+0·2	+0·3
Difference	+0·1	+0·1	−0·1	−0·1	−0·2	−0·3

The differences do not, however, remain constant, even approximately. The present comparison indicates larger errors for values of Δ greater than 75° than the Zagreb tables admit.

It thus appears that the moment is not yet come to suggest corrections to the tables which are likely to meet with general acceptance. It seems better to retain the old tables until a much greater mass of material has been discussed, and the old tables will accordingly be used for the comparisons made at Shide at any rate for the observations of 1911. The discussion of some 100 earthquakes should provide corrections approximating to definitive ones. Meanwhile, the best available corrections to the tables from the material above discussed, incorporating the information derived from the next section, are given at the end of the next section.

IX.—*Discussion in Azimuth.*

If the receiving stations are arranged in azimuth (A) round the epicentre, then

(*a*) Assuming the velocity of transmission constant in all azimuths, any error (δ) of position of the epicentre will give rise to an error

$$c + e \cos (A - A_0)$$

in the observed times at the stations: where A_0 is the azimuth in which the epicentre is erroneously displaced; A is the azimuth of the receiving

station; e is the effect of the displacement (δ) on P or S, as the case may be, at the distance of the receiving station; and c is a constant depending on the position of Pulkovo, or other station from which the epicentre is determined.

(b) If the velocity of transmission varies with the azimuth, then, if the velocity in azimuth A is not the same as in azimuth A + 180°, there will be a first-order harmonic which will be mixed up with that just written, due to the error in position of epicentre; and it may be difficult to separate the two. If, however, the velocity is the same for A and A + 180°, then we may look for a second-order harmonic to represent the variation. It will be seen from what follows that there are no trustworthy indications of such terms from the material now discussed. The material is insufficient to pronounce definitely against the existence of such terms, especially with small coefficients; but it is apparently sufficient to discredit any large term of the kind. For instance, Milne suggested a velocity N. and S. sensibly less, in the case of the large waves, from the velocity E. and W. (Eighteenth Report, § v). No such difference can be detected in the velocities for P and S.

We will first give in some detail the results for a single earthquake, that of 1913, January 11, adopted epicentre 6° N., 117° E. The residuals for P, when corrected for distance from epicentre as in Section IV., and arranged in azimuth measured from the N. point round the epicentre in the direction N., E., S., W., are as shown in Table VIII.

We see at a glance the better distribution of the Milne pendulums; most of the modern pendulums are in Europe and appear in the same azimuth-class 300°—330°. Were it not for the Milne instruments we should have very scanty material for an azimuth discussion; and yet this is one of the most favourable cases. The inferiority of the Milne instrument suggests giving a smaller weight to its records, but it will be seen that we should gain very little thereby. Taking the simple means as in the last column and filling in vacant terms by simple interpolation (in brackets), we can make a very rough harmonic analysis, obtaining

$$-1{\cdot}6 + 7{\cdot}5 \cos (A-330^\circ) + 2{\cdot}7 \cos 2\,(A - 70^\circ).$$

Treating the S observations in the same way, we get Table IX.

The material for discussion in azimuth is even more scanty and uncertain than before; but, analysing it for what it is worth, we get

$$-1{\cdot}2 + 8{\cdot}0 \cos (A - 332^\circ) + 4{\cdot}7 \cos 2\,(A - 177^\circ).$$

Now, considering the nature of the material and of the process used, it is somewhat remarkable that the results from P and S should accord so well in indicating a correction to the epicentre. The direction is in azimuth 331° say, and as the azimuth of Pulkovo is 330°, it is pretty clear that the estimated Δ for Pulkovo is in error, owing doubtless to the errors of the tables. The *amount* of displacement is not so easy to assess. In the above simple process we have treated all stations, at whatever distance from the epicentre, alike. A displacement of the epicentre of 1° will, however, alter the times of arrival of P by 16 s. near the epicentre, by 5½ s. at 90°, and by less still at greater distances. Nevertheless, on calculating the alterations for the actual distances, the mean

TABLE VIII.

Distribution of errors of P in azimuth round epicentre, 1913, *January* 11.

(The unit is 0·1 m. or 6 secs.)

(*a*) *Instruments other than Milne.*

0°—30°	—60°	—90°	—120°	—150°	—180°	—210°	—240°	—270°	—300°	—330°	—360°
+4 +3 −4				−12	+1		0			+17 +7 +7 +6 +4 +4 +4 +3 +2 +2 +1 −5 −6	+3

(*b*) *Milne Instruments.*

0°—30°	—60°	—90°	—120°	—150°	—180°	—210°	—240°	—270°	—300°	—330°	—360°
+11		−1		−9 −12	−16	−13	0	+3	+9 +5 +2	+14 −9	
+4	(+2)	−1	(−6)	−11	−8	−13	0	+3	+5	+3	+3

TABLE IX.

Distribution of errors of S in azimuth round epicentre, 1913, *January* 11.

(The unit is 0·1 m. or 6 secs.)

	0°—30°	—60°	—90°	—120°	—150°	—180°	—210°	—240°	—270°	—300°	—330°	—360°
(a) *Instruments other than Milne.*	+15 +5					+3		−16 −5 −5			+13 +11 +4 +4 −1 −1 −3 −5 −7 −8	+11
(b) *Milne Instruments.*	−5				−10 −16 −20					+6	+23 −8 −18	+22
Mean	+5	(0)	(−5)	(−10)	−15	+3	(−3)	−9	(−2)	+6	0	+16

for the different groups was found to be nearly constant at about 8 s. Since the coefficient (8 units of 0·1 m.) means 48 s., we may take it that the epicentre is about 6° wrong. As regards direction, note that the observed times for receiving stations on the side of the epicentre remote from Pulkovo are too small; so that the epicentre must be moved nearer to them and further from Pulkovo. The observed S–P at Pulkovo, viz. 10 m. 24 s., does not correspond (as indicated by the present tables) to an epicentral distance of 83°·5, but to a distance of 89°·5.

Turning to S, we find the average value of 1° to be about 13 s. The first harmonic of S thus indicates a displacement of 48°/13 or 3°·7. We may regard this as a satisfactory confirmation of the magnitude of the error, which may be put at about 5°.

The second harmonics in both cases are small, and the phases are quite discordant. We may fairly say that there is no evidence of a variation in velocity of an elliptic type.

As regards other earthquakes analysed for azimuth the following notes will suffice:—

1913, *March* 14. *Epicentre* 11° *N.*, 123° *E.*, *distant* 82° *from Pulkovo*

Of nearly same type as that of 1913, January 11, but distribution of stations not so good. The numbers in the 30° divisions for P are

1 1 0 0 1 2 1 1 1 4 33 5

and the harmonic expression is (in units of 0·1 m.)

$$+ 0{\cdot}2 + 5{\cdot}0 \cos (A - 302^\circ) + 4{\cdot}0 \cos 2 (A - 36^\circ).$$

For S the number of stations are

1 1 0 0 0 6 0 0 0 2 24 3

and the harmonic expression is

$$- 7{\cdot}8 + 14{\cdot}5 \cos (A - 345^\circ) - 4{\cdot}2 \cos 2 (A - 7^\circ).$$

In spite of the broken nature of the series, the indication of an error of about 4° or 5° in Δ is tolerably plain. The azimuth of Pulkovo is 330°, and the magnitudes of the displacement assigned by the P observations may be put at 30°/8 = 3°·8.
,, S ,, ,, ,, 87°/13 = 6°·7.

There is some indication of a second order term, but it cannot be regarded very seriously.

1913, *March* 23. *Epicentre* 26° *N.*, 143° *E.*, *distant* 78° *from Pulkovo.*

The only available observations between azimuths 0° and 210° are two Milne observations of P and one Milne of S. There seems no advantage in making even a rough estimate.

1913, *April* 30. *Epicentre* 50° *N.*, 176° *E.*, *distant* 67° *from Pulkovo.*

Number of observations in the separate groups

for P	4	2	0	0	1	0	0	0	3	1	3	14
for S	4	3	1	0	0	1	0	0	1	2	1	10

Harmonic expressions

from P $+2{\cdot}1 + 2{\cdot}7 \cos(A - 207°) + 3{\cdot}6 \cos 2(A - 73°)$
from S $+0{\cdot}5 + 11{\cdot}0 \cos(A - 235°) + 2{\cdot}6 \cos 2(A - 160°)$

Azimuth of Pulkovo being 342°, the mean direction of displacement (azimuth 220° say) is nearly at right angles to the direction of Pulkovo, and cannot be wholly explained by an error of tables. The small component in the line joining epicentre to Pulkovo is in the opposite direction to that previously noted.

1913, *June* 14. *Epicentre* 43° *N.*, 26° *E.*, *distant* 17° *from Pulkovo.*

There are unfortunately no observations of S from azimuth 90° to 270°, so that we cannot make any analysis. The mean results for the other azimuths are

Azimuth	270°—300°	—330°	—0°	—30°	—60°	—90°
Mean	+1	−4	−2	−4	+4	0
No observations	4	4	11	2	2	1

which suggest a displacement in the opposite direction to that of January 11 and March 14, and in the same direction as the component of April 30.

The numbers for P are

1 4 1 2 0 0 1 0 4 3 11 2

and the harmonic expression is

$$+2{\cdot}1 + 2{\cdot}8 \cos(\theta - 165°) + 1{\cdot}6 \cos 2(\theta - 111°)$$

The azimuth of Pulkovo being 7°, the small displacement indicated is nearly radial and in the opposite direction to those of January 11 and March 14.

Hence, so far as this evidence goes, the error of S–P is about 30 s. at 85°, diminishes at lesser distances, and changes to a small negative value. The corrections needed by the Galitzin tables would seem to be approximately as follows:—

	$\Delta =$ 15°	25°	35°	45°	55°	65°	75°	85°	95°	105°
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
Correction P =	0	0	0	0	0	−1	−3	−8	−15	−24
Correction S =	+5	0	−4	−8	−11	−14	−17	−24	−35	−50
Correction (S–P) =	+5	0	−4	−8	−11	−13	−14	−16	−20	−26
Correction Δ =	−5	0	+6	+13	+18	+24	+28	+31	+42	+52

the correction to Δ being expressed in units of $0°{\cdot}1$.

Investigation of the Upper Atmosphere.—Thirteenth Report of the Committee, consisting of Dr. W. N. SHAW (*Chairman*), Mr. E. GOLD (*Secretary*), Messrs. C. J. P. CAVE *and* W. H. DINES, Dr. R. T. GLAZEBROOK, Sir J. LARMOR, Professor J. E. PETAVEL, Dr. A. SCHUSTER, *and* Dr. W. WATSON.

A MEETING of the Joint Committee was held in the rooms of the Royal Meteorological Society on May 5, 1914. It was decided to allocate the grant from the British Association towards the expense of investigations with pilot balloons over the ocean to be undertaken by the Secretary on the journey to Australia, *via* the Cape of Good Hope. An

additional grant was made from the funds of the Royal Meteorological Society to enable simultaneous observations to be made by Dr. W. Rosenhain, of the National Physical Laboratory, on the journey *via* the Suez Canal. A report on the observations is in preparation and will be published in due course.

The report by Mr. G. I. Taylor on the observations which he made on board the *Scotia* in 1913, referred to in the Committee's report last year, has been published in the official account of the results of the *Scotia* Expedition, issued by the Board of Trade. The results which Mr. Taylor obtained throw much light on the formation of fog and on the propagation of heat through the atmosphere by means of eddies. He found generally that thick fogs were associated with a large increase in the temperature of the air in a vertical direction, while light fogs occurred when the increase was small.

The Committee records with regret the death during the year of Mr. Douglas Archibald, who was one of the earliest investigators of the upper air by means of kites, and had served on the Committee since its appointment at Glasgow in 1901.

The Committee asks for reappointment, with a grant of 25*l.*

Radiotelegraphic Investigations.—Interim Report of the Committee, consisting of Sir OLIVER LODGE *(Chairman)*, Dr. W. H. ECCLES *(Secretary)*, Mr. SIDNEY G. BROWN, Dr. C. CHREE, Professor A. S. EDDINGTON, Dr. ERSKINE-MURRAY, Professors J. A. FLEMING, G. W. O. HOWE, *and* H. M. MACDONALD, Sir H. NORMAN, Captain H. R. SANKEY, Professor A. SCHUSTER, Dr. W. N. SHAW, *and* Professor S. P. THOMPSON.

THE past year has been occupied mainly by the designing, printing, and distribution of books of forms for recording observations, by the enrolment of observers, and by the preliminary work in connection with the observations to be made during the forthcoming solar eclipse.

I. *Collection of Ordinary Daily Statistics.*

We have obtained the cordial support of many Government Departments of the British Empire and of other countries. In the British Empire the Navy has taken forms sufficient to distribute to about 120 ships. The Post Office has sent forms to nine stations. The Government of Canada have undertaken to get statistics from four stations on the Pacific Coast. The South African Government have authorised the collection of statistics at Cape Town and Durban. The Australian Government have brought eight stations into the scheme, and the New Zealand Government and the Indian Government each several stations. The Colonial Office has kindly circularised other of the Colonies, and of these the following have already replied favourably, and have had supplies of forms despatched to them:—

Falkland Islands.	**Zanzibar.**	**British Guiana.**
Bahamas	**Somaliland.**	**Jamaica.**
Trinidad.	**Fiji.**	**Sierra Leone.**
Ceylon.	**Gold Coast.**	

The Government of Norway have agreed to have statistics collected at four stations; the United States Government at five; in Germany the Telegraphs Versuchsamt is making observations at Berlin, and there are some Russian Government stations likely to co-operate.

The following Companies are taking a prominent part in the collection of statistics: The Marconi International Marine Communication Company, Ltd., have already twenty-three ships at work; the Marconi Company of Canada have thirteen stations at work on the East Coast of Canada, in Newfoundland and on the Great Lakes; the American Marconi Company have put fifteen land stations (between Alaska and the Gulf of Mexico) to work, and several ships; the Federal Wireless Telegraph Company of America have started observations at their San Francisco station; the Gesellschaft für drahtlose Telegraphie will put a considerable number of stations to work as soon as forms have been translated, and they have the intention of establishing a small prize scheme amongst their operators for the best series of observations. At the Slough station the Anglo-French Wireless Company started observations which will be continued by the Galletti Company; while the English Marconi Company are doing the like at Chelmsford.

With regard to Russia, the language difficulty was likely to prove formidable, but the Editor of the Russian 'Journal of Wireless Telegraphy' has arranged that the forms be translated into Russian and that the collection of statistics be urged upon readers of his Journal. The Société Russe de Télégraphes et Téléphones sans Fil have agreed that the forms, when translated, shall be used at a number of the stations under the control of the Company in Russia.

Among private experimenters of note we have obtained the support of several gentlemen abroad, who will doubtless have to be mentioned in subsequent reports. There are also a number of Professors in the British Isles and in the Colonies helping, and about sixty-one amateurs. Of these there are thirty-six in England, two in Scotland, six in Ireland, and one in Wales.

A considerable number of completed forms have already come to hand and a start has been made on the analysis.

II. *Observations to be made during the Eclipse of August* 21, 1914.

The central line of the eclipse passes across Norway, Sweden, the Baltic, Central Russia, the Black Sea, and Persia, to the coast of India. Accordingly, the Governments of Norway, Sweden, Russia, and India have been approached. The Norwegian Government have generously placed practically all their stations at the disposal of the Committee; the Swedish Government have agreed that the observations they wish to make on their own behalf shall be made in accord with the programme of the Committee, to whom copies will be supplied; and the Russian Government will set a number of stations to work, but the number and position of these have not yet been settled. The Société Russe will place their high-power station at St. Petersburg at the disposal of the Committee, and the Gesellschaft für drahtlose Telegraphie is also willing to allow two or three large stations to come into the scheme. This

Company will enact that observations on the day of the eclipse shall be compulsory in many of its stations in the Baltic and in Germany. The Indian Government have agreed to help also. In Western Europe the transmission of special signals is not of such great importance as in the districts nearer the central line of the eclipse, but some observations ought to be instituted on signals in that part of the world. The Marconi Company have kindly expressed their willingness to aid the Committee by transmitting from certain high-power stations a few special signals, if desired, at times to be arranged by the Committee.

Many private observers in different parts of the world have signified their willingness to make a special effort on the day of the eclipse. It has been explained to the authorities in the United States, Canada, Australia, South Africa, and New Zealand, that although there is not much likelihood of the effects of the eclipse being perceived in their territories, yet they will be advised of the programme of the Committee, in order that they may, if they will, determine precisely whether there is, or is not, any effect. Since it seemed important to enlist the sympathies of as large a number as possible of skilled observers on the Eastern boundaries of Germany, Austria, and Hungary, the Editor of the 'Jahrbuch für drahtlose Telegraphie' was asked, and has agreed, to seek German-speaking observers, conduct all preliminary correspondence with them, translate forms and get them printed and distributed, and to collect the forms. It has recently been arranged that a large proportion of this work may be shared with the International Commission of Brussels.

In addition to all this welcome assistance, we are especially glad to report that the Board of the Admiralty have agreed to co-operate on an extensive scale.

The Relations between this Committee and the International Commission of Brussels.

As a member of the British Section of the International Commission, the Secretary was made a delegate to the recent Conference in Brussels, and there suggested that it might be to the advantage of both organisations, especially when requesting assistance from Government Departments or Companies, or even private experimenters, that a public announcement should be made showing that the aims of the two bodies are different, that there is room for both, that there is little danger of any Government or Company or private experimenter being asked to do the same thing twice, or to favour one to the detriment of the other; and that if on any occasion there were overlapping, then the two organisations should endeavour to co-operate. The International Commission therefore drew up and passed the following resolution:—

'La Commission Internationale de T.S.F.S., ayant pris connaissance du but des travaux du "Committee for Radio-telegraphic Investigation of the British Association," estime que les travaux des deux organisations ont des objets différents.

'La Commission Internationale de T.S.F.S. se propose, en effet, de faire des recherches qui portent principalement sur les mesures quantita-

tives se rapportant à l'émission, à la propagation et à la réception des ondes électriques.

'L'Association Britannique a décidé, de son côté, de recueillir, de classer et de commenter les résultats des observations susceptibles de faire ressortir les relations entre les phénomènes géophysiques et la propagation des ondes électriques. Il entre également dans ses vues de dresser la statistique et de faire l'étude des phénomènes anormaux et des perturbations atmosphériques.

'En conséquence, si les champs d'activité des deux organisations viennent à avoir des points communs, la Commission Internationale de T.S.F.S. engage ses adhérents à prêter éventuellement le concours le plus complet à la "British Association."'

At a meeting of the British Association Committee on May 8, 1914, the following resolution was adopted:—

'That the Radiotelegraphic Investigation Committee of the British Association for the Advancement of Science take cognisance of the resolution adopted by the Commission Internationale de Télégraphie sans Fils Scientifique at the recent conference in Brussels, and desire to affirm that they find themselves in full accord with the definitions, as expressed in the resolution, of the differences between the aims and methods of the researches promoted by the two organisations; while, in regard to those researches in which the two bodies both take an active interest, this Committee warmly welcome and value highly the offer of co-operation, and gladly undertake to give all assistance in their power.'

The Committee has expended up to the present in office expenses, printing, and distribution of forms, the sum of 144*l.*

[NOTE.—The following communication was circulated to Members of the Committee by the Secretary on behalf of the Chairman in December, 1914:—

The war has naturally had a very direct effect on radiotelegraphic investigations. About August 1 last, private wireless telegraph stations throughout the Empire were nearly all dismantled or taken possession of by military authorities, while naval and other Government stations stopped all merely scientific observing. The radiotelegraphic stations in Russia, Germany, and neighbouring countries doubtless discontinued the filling up of our forms as soon as mobilisation began. A few stations in India, Australia, Canada, the West Indies, and the United States are, however, still at work. In the last-named country about thirty stations are making observations.

The Committee's programme for the collection of statistics three days a week in all parts of the English-speaking world and in a few other countries was planned to embrace one complete round of the seasons. The fact that the programme has been interrupted after only three months of really full work diminishes greatly the scientific value of such statistics as have been collected. It also implies considerable financial loss. A large batch of forms was distributed to our Navy in July: in clearing for action these forms would probably be wasted. The German edition was distributed in June. The Russian edition also was probably distributed before the outbreak of war.

The extensive scheme of special observations projected for the occasion of the solar eclipse failed almost completely in the countries in which the eclipse was visible. A small amount of work was done in Norway and Sweden. All the necessary forms had been printed, and some had been circulated before the war started. The financial loss to the Committee in this respect exceeds a hundred pounds.

The day-by-day statistics collected in the period April to July are now being analysed. The conclusions drawn from these observations will, it may be hoped, have some scientific value of their own, and in any case they should yield information which may guide the Committee, when the time comes, to further attacks on the problems concerned. A similar thought may be set down as consolation for the eclipse failure.

In October last, at a special meeting summoned by the Inspector of Wireless Telegraphy at the General Post Office, where it happened that the Committee were represented by Dr. Erskine-Murray and the Secretary, the Committee were asked to draw up for the Home Office a list of gentlemen distributed over the British Isles who would be willing, if and when called upon, to assist the police by acting as voluntary experts in wireless telegraphy. The police cannot in general be expected to possess sufficient technical knowledge to discriminate between dangerous radiotelegraphic apparatus and other apparatus. Co-operation with the police authorities in each locality by someone possessing technical knowledge will help to prevent blunders and may assist in detecting illicit traffic. Accordingly gentlemen whose names appear in the address book of the Committee have been written to, and lists of voluntary experts have been supplied to the Home Office.]

Establishing a Solar Observatory in Australia.—Report of the Committee, consisting of Professor H. H. TURNER (*Chairman*), Dr. W. G. DUFFIELD (*Secretary*), Rev. A. L. CORTIE, Dr. F. W. DYSON, *and* Professors A. S. EDDINGTON, H. F. NEWALL, J. W. NICHOLSON, *and* A. SCHUSTER, *appointed to aid the work of Establishing a Solar Observatory in Australia.*

THE Committee records with great sorrow the death of its former Chairman Sir David Gill, whose name has always been so prominently associated with scientific enterprises connected with the Southern Hemisphere. Professor H. H. Turner has been appointed Chairman in his place.

The Secretary has great pleasure in reporting that the following letter has been received from the Commonwealth Authorities in response to further representations regarding the desirability of erecting a Solar Observatory within the Commonwealth:—

Commonwealth Offices,
72 Victoria Street, Westminster, S.W.
March 10, 1914.

Dear Dr. Duffield,

With reference to previous correspondence in regard to the establishment of a Solar Observatory in Australia, I desire to inform you that I have now received a memorandum from the Commonwealth Government advising that in the scheme for the organisation of services in connection with the Seat of Government at Canberra, provision has been made for the establishment amongst general astronomical studies of a section to be devoted to solar physics in particular.

Yours sincerely,
(Signed) R. MUIRHEAD COLLINS.

Dr. Geoffrey Duffield,
University College, Reading.

The Committee records its great satisfaction at the promise of the

institution of Solar Research in Australia—an end for which it has worked since its appointment at the Dublin Meeting of the Association in 1908. The Prime Minister of the Commonwealth has consented to receive a deputation of overseas astronomers with regard to the nature of the solar work which should be undertaken in Australia.

The Calculation of Mathematical Tables.—Report of the Committee, consisting of Professor M. J. M. HILL *(Chairman)*, Professor J. W. NICHOLSON *(Secretary)*, Mr. J. R. AIREY, Professor L. N. G. FILON, Sir GEORGE GREENHILL, Professor E. W. HOBSON, Professor ALFRED LODGE, Professor A. E. H. LOVE, Professor H. M. MACDONALD, *and* Professor A. G. WEBSTER.

THE grant given to the Committee during the past year has been expended on the calculation of the Logarithmic Bessel Functions, for which it was specially allocated. In the present report are Tables of the functions $Y_0(x)$ and $Y_1(x)$, whose significance was explained on page 29 of the last report. These proceed from argument $x = 0{\cdot}02$ to $x = 15{\cdot}50$, at intervals of 0·02, and are correct to six significant figures.

Some further Tables of the functions $G_n(x)$ are also included, for varying order n of the functions. These are incomplete at present. The Committee is proceeding with the further calculation of the functions $Y_2(x)$, $Y_3(x)$, ... on the same scale as the present Tables of Y_0 and Y_1.

The Committee desires to ask for a further grant of 30*l.* during the coming year, to be allocated to this work.

Some Tables calculated by Mr. Doodson, of the University of Liverpool, are given at the end of the report. They deal with the functions of type $J_{n+\frac{1}{2}}(x)$, where n is a positive or negative integer. A considerable demand for these Tables exists at present. Mr. Doodson is continuing this work, and it is suggested that his name be added to the Committee. The previous requisition that a large number of copies of the report (about 100) should be placed in the hands of the Secretary for distribution is repeated, as the demand for these Tables from physicists is increasing.

Tables of the Neumann Functions $Y_0(x)$ *and* $Y_1(x)$ *or Bessel Functions of the Second Kind.*

The second solution of Bessel's differential equation

$$x^2\frac{d^2y}{dx^2} + x\frac{dy}{dx} + (x^2 - n^2)\,.\,y = 0$$

has been given in several forms—$G_n(x)$, $Y_n(x)$, $K_n(x)$, &c. Tables of $G_0(x)$ and $G_1(x)$ for values of x from 0·01 to 16·00 by intervals of 0·01 were published in the report for 1913.

Short Tables of the $Y_0(x)$ and $Y_1(x)$ functions defined by

$$Y_0(x) = J_0(x)\,.\,\log_e x + \left(\frac{x}{2}\right)^2 - (1 + \tfrac{1}{2})\left(\frac{x}{2}\right)^4\Big/2\,!^2$$
$$+ (1 + \tfrac{1}{2} + \tfrac{1}{3})\left(\frac{x}{2}\right)^6\Big/3\,!^2 - .$$

$$Y_1(x) = J_1(x) \cdot \log_e x - J_0(x)/x - \frac{x}{2} + (1 + \tfrac{1}{2})\left(\frac{x}{2}\right)^3/1!\,2!$$
$$- (1 + \tfrac{1}{2} + \tfrac{1}{3})\left(\frac{x}{2}\right)^5/2!\,3! + \ldots$$

have been calculated by B. A. Smith for $x = 0{\cdot}01$ to $1{\cdot}00$ and $1{\cdot}0$ to $10{\cdot}2$ to four places of decimals, and by J. R. Airey for $x = 0{\cdot}1$ to $16{\cdot}0$ to seven places.

The following Tables have been computed from the relation

$$Y_n(x) = (\log 2 - \gamma)\, J_n(x) - G_n(x)$$

and verified by the method of differences.

The interpolation formulæ for other values of the argument are

$$Y_0(x \pm h) = \left[1 - \frac{h^2}{2} \pm \frac{h^3}{6x} \ldots\right] Y_0(x) + \left[\mp h + \frac{h^2}{2x} \ldots\right] Y_1(x)$$

$$Y_1(x \pm h) = \left[1 \mp \frac{h}{x} - \frac{h^2}{2}\left(1 - \frac{2}{x^2}\right) \ldots\right] Y_1(x) + \left[\pm h - \frac{h^2}{2x} \ldots\right] Y_0(x).$$

Tables of the Neumann Cylinder Functions.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
0·02	−3·911532	−50·044118	0·76	−0·099484	−1·569515
0·04	−3·217189	−25·074360	0·78	−0·068482	−1·530927
0·06	−2·809980	−16·766014	0·80	−0·038237	−1·493705
0·08	−2·520090	−12·620908	0·82	−0·008725	−1·457735
0·10	−2·294335	−10·139907	0·84	+0·020080	−1·422912
0·12	−2·109042	−8·490185	0·86	+0·048199	−1·389144
0·14	−1·951600	−7·314934	0·88	+0·075652	−1·356346
0·16	−1·814487	−6·435818	0·90	+0·102458	−1·324442
0·18	−1·692861	−5·753809	0·92	+0·128635	−1·293362
0·20	−1·583421	−5·209517	0·94	+0·154198	−1·263043
0·22	−1·483817	−4·765173	0·96	+0·179162	−1·233429
0·24	−1·392318	−4·395614	0·98	+0·203539	−1·204467
0·26	−1·307611	−4·083430	1·00	+0·227344	−1·176110
0·28	−1·228681	−3·816195	1·02	+0·250588	−1·148315
0·30	−1·154725	−3·584806	1·04	+0·273280	−1·121042
0·32	−1·085096	−3·382440	1·06	+0·295433	−1·094256
0·34	−1·019269	−3·203886	1·08	+0·317054	−1·067922
0·36	−0·956809	−3·045093	1·10	+0·338152	−1·042011
0·38	−0·897355	−2·902869	1·12	+0·358737	−1·016496
0·40	−0·840601	−2·774662	1·14	+0·378815	−0·991350
0·42	−0·786269	−2·658408	1·16	+0·398393	−0·966551
0·44	−0·734196	−2·552423	1·18	+0·417479	−0·942079
0·46	−0·684132	−2·455317	1·20	+0·436078	−0·917912
0·48	−0·635932	−2·365931	1·22	+0·454197	−0·894033
0·50	−0·589450	−2·283297	1·24	+0·471841	−0·870426
0·52	−0·544561	−2·206594	1·26	+0·489016	−0·847076
0·54	−0·501152	−2·135127	1·28	+0·505726	−0·823970
0·56	−0·459125	−2·068299	1·30	+0·521976	−0·801094
0·58	−0·418392	−2·005598	1·32	+0·537771	−0·778438
0·60	−0·378875	−1·946580	1·34	+0·553115	−0·755991
0·62	−0·340507	−1·890861	1·36	+0·568012	−0·733743
0·64	−0·303222	−1·838105	1·38	+0·582466	−0·711687
0·66	−0·266965	−1·788017	1·40	+0·596481	−0·689814
0·68	−0·231685	−1·740338	1·42	+0·610060	−0·668116
0·70	−0·197337	−1·694840	1·44	+0·623207	−0·646589
0·72	−0·163878	−1·651320	1·46	+0·635925	−0·625226
0·74	−0·131272	−1·609599	1·48	+0·648217	−0·604021

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
1·50	+0·660086	−0·582971	2·68	+0·714906	+0·397539
1·52	+0·671537	−0·562070	2·70	+0·706843	+0·408760
1·54	+0·682570	−0·541317	2·72	+0·698557	+0·419757
1·56	+0·693190	−0·520706	2·74	+0·690054	+0·430529
1·58	+0·703399	−0·500237	2·76	+0·681338	+0·441073
1·60	+0·713200	−0·479905	2·78	+0·672413	+0·451389
1·62	+0·722596	−0·459710	2·80	+0·663284	+0·461474
1·64	+0·731590	−0·439650	2·82	+0·653955	+0·471327
1·66	+0·740183	−0·419723	2·84	+0·644432	+0·480947
1·68	+0·748380	−0·399929	2·86	+0·634719	+0·490331
1·70	+0·756181	−0·380266	2·88	+0·624821	+0·499477
1·72	+0·763591	−0·360734	2·90	+0·614742	+0·508385
1·74	+0·770612	−0·341333	2·92	+0·604487	+0·517054
1·76	+0·777245	−0·322063	2·94	+0·594061	+0·525482
1·78	+0·783495	−0·302924	2·96	+0·583469	+0·533667
1·80	+0·789363	−0·283916	2·98	+0·572716	+0·541608
1·82	+0·794853	−0·265040	3·00	+0·561806	+0·549305
1·84	+0·799966	−0·246297	3·02	+0·550745	+0·556756
1·86	+0·804705	−0·227687	3·04	+0·539538	+0·563960
1·88	+0·809074	−0·209212	3·06	+0·528189	+0·570917
1·90	+0·813075	−0·190874	3·08	+0·516703	+0·577625
1·92	+0·816710	−0·172672	3·10	+0·505085	+0·584083
1·94	+0·819982	−0·154608	3·12	+0·493341	+0·590291
1·96	+0·822895	−0·136685	3·14	+0·481475	+0·596249
1·98	+0·825451	−0·118904	3·16	+0·469493	+0·601955
2·00	+0·827652	−0·101266	3·18	+0·457399	+0·607408
2·02	+0·829502	−0·083773	3·20	+0·445198	+0·612620
2·04	+0·831004	−0·066427	3·22	+0·432896	+0·617559
2·06	+0·832161	−0·049231	3·24	+0·420498	+0·622254
2·08	+0·832974	−0·032186	3·26	+0·408008	+0·626696
2·10	+0·833449	−0·015294	3·28	+0·395431	+0·630885
2·12	+0·833587	+0·001443	3·30	+0·382774	+0·634820
2·14	+0·833392	+0·018022	3·32	+0·370040	+0·638501
2·16	+0·832867	+0·034441	3·34	+0·357236	+0·641929
2·18	+0·832016	+0·050698	3·36	+0·344365	+0·645103
2·20	+0·830841	+0·066791	3·38	+0·331433	+0·648024
2·22	+0·829345	+0·082717	3·40	+0·318446	+0·650691
2·24	+0·827533	+0·098473	3·42	+0·305407	+0·653106
2·26	+0·825407	+0·114058	3·44	+0·292323	+0·655269
2·28	+0·822972	+0·129470	3·46	+0·279198	+0·657180
2·30	+0·820230	+0·144705	3·48	+0·266038	+0·658840
2·32	+0·817185	+0·159762	3·50	+0·252846	+0·660249
2·34	+0·813841	+0·174637	3·52	+0·239629	+0·661408
2·36	+0·810201	+0·189329	3·54	+0·226392	+0·662318
2·38	+0·806269	+0·203836	3·56	+0·213138	+0·662980
2·40	+0·802048	+0·218154	3·58	+0·199874	+0·663395
2·42	+0·797544	+0·232281	3·60	+0·186604	+0·663564
2·44	+0·792758	+0·246215	3·62	+0·173333	+0·663487
2·46	+0·787696	+0·259954	3·64	+0·160066	+0·663166
2·48	+0·782362	+0·273495	3·66	+0·146808	+0·662602
2·50	+0·776758	+0·286837	3·68	+0·133564	+0·661797
2·52	+0·770889	+0·299976	3·70	+0·120338	+0·660752
2·54	+0·764760	+0·312910	3·72	+0·107135	+0·659468
2·56	+0·758374	+0·325637	3·74	+0·093961	+0·657947
2·58	+0·751736	+0·338156	3·76	+0·080819	+0·656190
2·60	+0·744850	+0·350464	3·78	+0·067715	+0·654199
2·62	+0·737719	+0·362558	3·80	+0·054653	+0·651976
2·64	+0·730349	+0·374436	3·82	+0·041637	+0·649523
2·66	+0·722743	+0·396097	3·84	+0·028673	+0·646841

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
3·86	+0·015765	+0·643933	5·04	−0·512543	+0·172467
3·88	+0·002917	+0·640800	5·06	−0·515883	+0·161521
3·90	−0·009866	+0·637444	5·08	−0·519004	+0·150556
3·92	−0·022579	+0·633868	5·10	−0·521905	+0·139577
3·94	−0·035219	+0·630073	5·12	−0·524587	+0·128587
3·96	−0·047781	+0·626063	5·14	−0·527048	+0·117590
3·98	−0·060260	+0·621839	5·16	−0·529290	+0·106591
4·00	−0·072653	+0·617404	5·18	−0·531312	+0·095594
4·02	−0·084955	+0·612760	5·20	−0·533114	+0·084602
4·04	−0·097162	+0·607909	5·22	−0·534696	+0·073619
4·06	−0·109270	+0·602855	5·24	−0·536059	+0·062650
4.08	−0·121275	+0·597600	5·26	−0·537202	+0·051700
4.10	−0·133172	+0·592146	5·28	−0·538127	+0·040771
4·12	−0·144959	+0·586497	5·30	−0·538833	+0·029867
4·14	−0·156631	+0·580655	5·32	−0·539322	+0·018994
4·16	−0·168184	+0·574623	5·34	−0·539593	+0·008154
4·18	−0·179615	+0·568403	5·36	−0·539648	−0·002650
4·20	−0·190919	+0·562000	5·38	−0·539488	−0·013412
4·22	−0·202093	+0·555415	5·40	−0·539112	−0·024128
4·24	−0·213134	+0·548652	5·42	−0·538523	−0·034796
4·26	−0·224038	+0·541715	5·44	−0·537721	−0·045411
4·28	−0·234802	+0·534605	5·46	−0·536707	−0·055970
4·30	−0·245422	+0·527327	5·48	−0·535482	−0·066468
4·32	−0·255894	+0·519884	5·50	−0·534048	−0·076903
4·34	−0·266216	+0·512279	5·52	−0·532406	−0·087270
4·36	−0·276384	+0·504515	5·54	−0·530558	−0·097566
4·38	−0·286395	+0·496596	5·56	−0·528504	−0·107786
4·40	−0·296247	+0·488525	5·58	−0·526247	−0·117929
4·42	−0·305936	+0·480306	5·60	−0·523788	−0·127990
4·44	−0·315458	+0·471943	5·62	−0·521128	−0·137965
4·46	−0·324812	+0·463438	5·64	−0·518270	−0·147852
4·48	−0·333995	+0·454795	5·66	−0·515215	−0·157646
4·50	−0·343003	+0·446018	5·68	−0·511964	−0·167345
4·52	−0·351834	+0·437112	5·70	−0·508521	−0·176945
4·54	−0·360487	+0·428078	5·72	−0·504887	−0·186443
4·56	−0·368957	+0·418921	5·74	−0·501064	−0·195836
4·58	−0·377243	+0·409646	5·76	−0·497055	−0·205120
4·60	−0·385342	+0·400255	5·78	−0·492861	−0·214293
4·62	−0·393252	+0·390753	5·80	−0·488484	−0·223350
4·64	−0·400971	+0·381144	5·82	−0·483927	−0·232290
4·66	−0·408497	+0·371430	5·84	−0·479194	−0·241110
4·68	−0·415828	+0·361617	5·86	−0·474284	−0·249806
4·70	−0 422961	+0·351708	5·88	−0·469202	−0·258375
4·72	−0·429895	+0·341706	5·90	−0·463949	−0·266815
4·74	−0·436629	+0·331617	5·92	−0·458529	−0·275123
4·76	−0·443160	+0·321444	5·94	−0·452945	−0·283297
4·78	−0·449486	+0·311191	5·96	−0·447199	−0·291333
4·80	−0·455607	+0·300862	5·98	−0·441293	−0·299229
4·82	−0·461520	+0·290461	6·00	−0·435231	−0·306982
4·84	−0·467225	+0·279992	6·02	−0·429015	−0·314590
4·86	−0·472719	+0·269459	6·04	−0·422648	−0·322051
4·88	−0·478003	+0·258867	6·06	−0·416134	−0·329363
4·90	−0·483074	+0·248219	6·08	−0·409474	−0·336522
4·92	−0·487931	+0·237519	6·10	−0·402674	−0·343527
4·94	−0·492574	+0·226772	6·12	−0·395735	−0·350376
4·96	−0·497002	+0·215981	6·14	−0·388660	−0·357066
4·98	−0·501213	+0·205151	6·16	−0·381453	−0·363595
5·00	−0·505208	+0·194286	6·18	−0·374117	−0·369961
5·02	−0·508984	+0·183390	6·20	−0·366656	−0·376164

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
6·22	−0·359072	−0·382201	7·40	+0·174739	−0·416299
6·24	−0·351369	−0·388069	7·42	+0·183019	−0·411604
6·26	−0·343550	−0·393768	7·44	+0·191203	−0·406760
6·28	−0·335619	−0·399295	7·46	+0·199288	−0·401770
6·30	−0·327579	−0·404649	7·48	+0·207272	−0·396635
6·32	−0·319434	−0·409828	7·50	+0·215153	−0·391359
6·34	−0·311187	−0·414832	7·52	+0·222926	−0·385943
6·36	−0·302842	−0·419657	7·54	+0·230589	−0·380390
6·38	−0·294402	−0·424305	7·56	+0·238140	−0·374702
6·40	−0·285871	−0·428773	7·58	+0·245577	−0·368882
6·42	−0·277253	−0·433060	7·60	+0·252895	−0·362933
6·44	−0·268550	−0·437165	7·62	+0·260093	−0·356857
6·46	−0·259767	−0·441086	7·64	+0·267168	−0·350657
6·48	−0·250908	−0·444824	7·66	+0·274118	−0·344335
6·50	−0·241976	−0·448377	7·68	+0·280941	−0·337895
6·52	−0·232974	−0·451743	7·70	+0·287633	−0·331339
6·54	−0·223907	−0·454924	7·72	+0·294193	−0·324670
6·56	−0·214778	−0·457917	7·74	+0·300619	−0·317890
6·58	−0·205592	−0·460723	7·76	+0·306909	−0·311003
6·60	−0·196351	−0·463340	7·78	+0·313059	−0·304012
6·62	−0·187059	−0·465768	7·80	+0·319068	−0·296919
6·64	−0·177721	−0·468008	7·82	+0·324935	−0·289727
6·66	−0·168340	−0·470058	7·84	+0·330657	−0·282440
6·68	−0·158920	−0·471918	7·86	+0·336232	−0·275061
6·70	−0·149465	−0·473589	7·88	+0·341659	−0·267593
6·72	−0·139978	−0·475069	7·90	+0·346935	−0·260038
6·74	−0·130463	−0·476360	7·92	+0·352060	−0·252399
6·76	−0·120925	−0·477461	7·94	+0·357031	−0·244681
6·78	−0·111366	−0·478372	7·96	+0·361846	−0·236886
6·80	−0·101791	−0·479093	7·98	+0·366505	−0·229018
6·82	−0·092203	−0·479626	8·00	+0·371007	−0·221079
6·84	−0·082607	−0·479969	8·02	+0·375348	−0·213073
6·86	−0·073006	−0·480123	8·04	+0·379529	−0·205003
6·88	−0·063403	−0·480090	8·06	+0·383548	−0·196873
6·90	−0·053804	−0·479868	8·08	+0·387404	−0·188686
6·92	−0·044211	−0·479460	8·10	+0·391095	−0·180445
6·94	−0·034627	−0·478865	8·12	+0·394621	−0·172152
6·96	−0·025057	−0·478085	8·14	+0·397981	−0·163812
6·98	−0·015504	−0·477120	8·16	+0·401173	−0·155429
7·00	−0·005973	−0·475972	8·18	+0·404198	−0·147005
7·02	+0·003533	−0·474640	8·20	+0·407053	−0·138543
7·04	+0·013011	−0·473126	8·22	+0·409739	−0·130048
7·06	+0·022457	−0·471431	8·24	+0·412255	−0·121522
7·08	+0·031867	−0·469557	8·26	+0·414600	−0·112969
7·10	+0·041238	−0·467504	8·28	+0·416773	−0·104392
7·12	+0·050566	−0·465274	8·30	+0·418775	−0·095795
7·14	+0·059848	−0·462868	8·32	+0·420605	−0·087181
7·16	+0·069080	−0·460288	8·34	+0·422262	−0·078553
7·18	+0·078258	−0·457534	8·36	+0·423747	−0·069914
7·20	+0·087380	−0·454609	8·38	+0·425059	−0·061269
7·22	+0·096442	−0·451514	8·40	+0·426198	−0·052621
7·24	+0·105440	−0·448250	8·42	+0·427164	−0·043972
7·26	+0·114371	−0·444820	8·44	+0·427957	−0·035326
7·28	+0·123231	−0·441225	8·46	+0·428577	−0·026687
7·30	+0·132018	−0·437467	8·48	+0·429024	−0·018058
7·32	+0·140729	−0·433548	8·50	+0·429299	−0·009442
7·34	+0·149359	−0·429470	8·52	+0·429402	−0·000843
7·36	+0·157907	−0·425234	8·54	+0·429333	+0·007737
7·38	+0·166368	−0·420843	8·56	+0·429093	+0·016293

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
8·58	+0·428682	+0·024823	9·76	+0·152558	+0·380212
8·60	+0·428100	+0·033324	9·78	+0·144931	+0·382406
8·62	+0·427349	+0·041792	9·80	+0·137263	+0·384445
8·64	+0·426428	+0·050223	9·82	+0·129555	+0·386327
8·66	+0·425340	+0·058615	9·84	+0·121811	+0·388053
8·68	+0·424084	+0·066964	9·86	+0·114034	+0·389622
8·70	+0·422662	+0·075268	9·88	+0·106227	+0·391034
8·72	+0·421074	+0·083524	9·90	+0·098393	+0·392288
8·74	+0·419321	+0·091728	9·92	+0·090536	+0·393385
8·76	+0·417405	+0·099876	9·94	+0·082659	+0·394323
8·78	+0·415327	+0·107966	9·96	+0·074764	+0·395104
8·80	+0·413087	+0·115996	9·98	+0·066856	+0·395727
8·82	+0·410687	+0·123962	10·00	+0·058936	+0·396193
8·84	+0·408129	+0·131860	10·02	+0·051009	+0·396500
8·86	+0·405413	+0·139689	10·04	+0·043077	+0·396650
8·88	+0·402542	+0·147445	10·06	+0·035144	+0·396643
8·90	+0·399516	+0·155126	10·08	+0·027213	+0·396479
8·92	+0·396338	+0·162728	10·10	+0·019286	+0·396158
8·94	+0·393008	+0·170249	10·12	+0·011367	+0·395681
8·96	+0·389528	+0·177686	10·14	+0·003460	+0·395049
8·98	+0·385901	+0·185036	10·16	−0·004434	+0·394262
9·00	+0·382127	+0·192297	10·18	−0·012310	+0·393320
9·02	+0·378209	+0·199465	10·20	−0·020165	+0·392224
9·04	+0·374149	+0·206539	10·22	−0·027998	+0·390975
9·06	+0·369948	+0·213517	10·24	−0·035804	+0·389574
9·08	+0·365609	+0·220394	10·26	−0·043580	+0·388021
9·10	+0·361133	+0·227169	10·28	−0·051323	+0·386318
9·12	+0·356523	+0·233840	10·30	−0·059031	+0·384466
9·14	+0·351781	+0·240404	10·32	−0·066701	+0·382464
9·16	+0·346908	+0·246858	10·34	−0·074329	+0·380316
9·18	+0·341907	+0·253201	10·36	−0·081912	+0·378020
9·20	+0·336780	+0·259430	10·38	−0·089449	+0·375580
9·22	+0·331530	+0·265544	10·40	−0·096935	+0·372996
9·24	+0·326159	+0·271539	10·42	−0·104367	+0·370269
9·26	+0·320670	+0·277414	10·44	−0·111744	+0·367400
9·28	+0·315064	+0·283167	10·46	−0·119063	+0·364392
9·30	+0·309344	+0·288795	10·48	−0·126319	+0·361245
9·32	+0·303513	+0·294297	10·50	−0·133511	+0·357961
9·34	+0·297573	+0·299672	10·52	−0·140637	+0·354541
9·36	+0·291527	+0·304917	10·54	−0·147692	+0·350987
9·38	+0·285377	+0·310030	10·56	−0·154675	+0·347302
9·40	+0·279126	+0·315009	10·58	−0·161583	+0·343486
9·42	+0·272778	+0·319853	10·60	−0·168414	+0·339541
9·44	+0·266334	+0·324561	10·62	−0·175164	+0·335469
9·46	+0·259796	+0·329131	10·64	−0·181832	+0·331271
9·48	+0·253169	+0·333561	10·66	−0·188414	+0·326950
9·50	+0·246455	+0·337850	10·68	−0·194909	+0·322508
9·52	+0·239656	+0·341996	10·70	−0·201314	+0·317947
9·54	+0·232776	+0·345999	10·72	−0·207626	+0·313268
9·56	+0·225817	+0·349856	10·74	−0·213844	+0·308474
9·58	+0·218783	+0·353567	10·76	−0·219964	+0·303566
9·60	+0·211675	+0·357131	10·78	−0·225985	+0·298547
9·62	+0·204498	+0·360546	10·80	−0·231905	+0·293419
9·64	+0·197254	+0·363811	10·82	−0·237722	+0·288185
9·66	+0·189947	+0·366926	10·84	−0·243433	+0·282846
9·68	+0·182578	+0·369890	10·86	−0·249035	+0·277405
9·70	+0·175152	+0·372701	10·88	−0·254528	+0·271864
9·72	+0·167671	+0·375359	10·90	−0·259909	+0·266225
9·74	+0·160139	+0·377862	10·92	−0·265176	+0·260491

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
10·94	−0·270328	+0·254665	12·12	−0·332007	−0·155112
10·96	−0·275362	+0·248748	12·14	−0·328841	−0·161460
10·98	−0·280277	+0·242743	12·16	−0·325550	−0·167733
11·00	−0·285071	+0·236653	12·18	−0·322133	−0·173929
11·02	−0·289743	+0·230480	12·20	−0·318593	−0·180046
11·04	−0·294290	+0·224228	12·22	−0·314932	−0·186082
11·06	−0·298711	+0·217898	12·24	−0·311150	−0·192034
11·08	−0·303005	+0·211492	12·26	−0·307251	−0·197899
11·10	−0·307170	+0·205014	12·28	−0·303235	−0·203676
11·12	−0·311205	+0·198467	12·30	−0·299104	−0·209364
11·14	−0·315109	+0·191853	12·32	−0·294861	−0·214959
11·16	−0·318879	+0·185175	12·34	−0·290507	−0·220460
11·18	−0·322515	+0·178435	12·36	−0·286043	−0·225864
11·20	−0·326016	+0·171637	12·38	−0·281473	−0·231170
11·22	−0·329380	+0·164783	12·40	−0·276797	−0·236376
11·24	−0·332607	+0·157875	12·42	−0·272018	−0·241479
11·26	−0·335695	+0·150917	12·44	−0·267139	−0·246478
11·28	−0·338643	+0·143912	12·46	−0·262160	−0·251372
11·30	−0·341451	+0·136862	12·48	−0·257084	−0·256158
11·32	−0·344118	+0·129771	12·50	−0·251914	−0·260834
11·34	−0·346642	+0·122640	12·52	−0·246652	−0·265399
11·36	−0·349023	+0·115473	12·54	−0·241299	−0·269851
11·38	−0·351261	+0·108274	12·56	−0·235859	−0·274189
11·40	−0·353354	+0·101044	12·58	−0·230333	−0·278412
11·42	−0·355302	+0·093786	12·60	−0·224723	−0·282517
11·44	−0·357105	+0·086504	12·62	−0·219032	−0·286503
11·46	−0·358762	+0·079200	12·64	−0·213263	−0·290369
11·48	−0·360273	+0·071878	12·66	−0·207418	−0·294114
11·50	−0·361637	+0·064540	12·68	−0·201500	−0·297737
11·52	−0·362854	+0·057189	12·70	−0·195510	−0·301235
11·54	−0·363924	+0·049828	12·72	−0·189451	−0·304608
11·56	−0·364847	+0·042460	12·74	−0·183326	−0·307855
11·58	−0·365623	+0·035088	12·76	−0·177138	−0·310974
11·60	−0·366251	+0·027715	12·78	−0·170888	−0·313965
11·62	−0·366731	+0·020344	12·80	−0·164580	−0·316827
11·64	−0·367065	+0·012977	12·82	−0·158216	−0·319558
11·66	−0·367251	+0·005617	12·84	−0·151799	−0·322158
11·68	−0·367289	−0·001732	12·86	−0·145331	−0·324626
11·70	−0·367181	−0·009068	12·88	−0·138815	−0·326961
11·72	−0·366927	−0·016387	12·90	−0·132253	−0·329163
11·74	−0·366526	−0·023688	12·92	−0·125649	−0·331231
11·76	−0·365979	−0·030967	12·94	−0·119005	−0·333163
11·78	−0·365288	−0·038221	12·96	−0·112323	−0·334960
11·80	−0·364451	−0·045447	12·98	−0·105607	−0·336622
11·82	−0·363470	−0·052643	13·00	−0·098859	−0·338147
11·84	−0·362345	−0·059807	13·02	−0·092082	−0·339536
11·86	−0·361078	−0·066935	13·04	−0·085279	−0·340787
11·88	−0·359668	−0·074024	13·06	−0·078452	−0·341901
11·90	−0·358117	−0·081071	13·08	−0·071604	−0·342878
11·92	−0·356426	−0·088075	13·10	−0·064738	−0·343717
11·94	−0·354595	−0·095032	13·12	−0·057856	−0·344418
11·96	−0·352625	−0·101939	13·14	−0·050962	−0·344981
11·98	−0·350517	−0·108795	13·16	−0·044058	−0·345406
12·00	−0·348273	−0·115596	13·18	−0·037147	−0·345694
12·02	−0·345894	−0·122340	13·20	−0·030231	−0·345843
12·04	−0·343380	−0·129024	13·22	−0·023314	−0·345855
12·06	−0·340733	−0·135645	13·24	−0·016398	−0·345729
12·08	−0·337955	−0·142202	13·26	−0·009485	−0·345466
12·10	−0·335046	−0·148692	13·28	−0·002580	−0·345067

Neumann Cylinder Functions—continued.

x	$Y_0(x)$	$Y_1(x)$	x	$Y_0(x)$	$Y_1(x)$
13·30	+0·004316	−0·344531	14·42	+0·299680	−0·129889
13·32	+0·011201	−0·343858	14·44	+0·302216	−0·123694
13·34	+0·018070	−0·343050	14·46	+0·304628	−0·117459
13·36	+0·024922	−0·342107	14·48	+0·306914	−0·111185
13·38	+0·031753	−0·341029	14·50	+0·309075	−0·104876
13·40	+0·038562	−0·339817	14·52	+0·311109	−0·098534
13·42	+0·045345	−0·338472	14·54	+0·313016	−0·092161
13·44	+0·052100	−0·336994	14·56	+0·314795	−0·085760
13·46	+0·058824	−0·335386	14·58	+0·316446	−0·079334
13·48	+0·065515	−0·333645	14·60	+0·317968	−0·072886
13·50	+0·072169	−0·331775	14·62	+0·319362	−0·066417
13·52	+0·078785	−0·329776	14·64	+0·320625	−0·059931
13·54	+0·085359	−0·327649	14·66	+0·321759	−0·053429
13·56	+0·091890	−0·325395	14·68	+0·322762	−0·046915
13·58	+0·098374	−0·323014	14·70	+0·323635	−0·040392
13·60	+0·104809	−0·320508	14·72	+0·324378	−0·033861
13·62	+0·111193	−0·317879	14·74	+0·324990	−0·027326
13·64	+0·117524	−0·315127	14·76	+0·325471	−0·020788
13·66	+0·123798	−0·312254	14·78	+0·325821	−0·014251
13·68	+0·130013	−0·309261	14·80	+0·326041	−0·007717
13·70	+0·136167	−0·306150	14·82	+0·326130	−0·001189
13·72	+0·142258	−0·302922	14·84	+0·326088	+0·005330
13·74	+0·148283	−0·299577	14·86	+0·325917	+0·011839
13·76	+0·154241	−0·296118	14·88	+0·325615	+0·018334
13·78	+0·160128	−0·292547	14·90	+0·325183	+0·024813
13·80	+0·165942	−0·288865	14·92	+0·324622	+0·031274
13·82	+0·171681	−0·285073	14·94	+0·323932	+0·037714
13·84	+0·177344	−0·281173	14·96	+0·323114	+0·044130
13·86	+0·182928	−0·277167	14·98	+0·322167	+0·050519
13·88	+0·188430	−0·273056	15·00	+0·321093	+0·056880
13·90	+0·193849	−0·268843	15·02	+0·319893	+0·063210
13·92	+0·199183	−0·264529	15·04	+0·318566	+0·069507
13·94	+0·204430	−0·260116	15·06	+0·317113	+0·075767
13·96	+0·209587	−0·255606	15·08	+0·315535	+0·081989
13·98	+0·214653	−0·251001	15·10	+0·313833	+0·088171
14·00	+0·219627	−0·246303	15·12	+0·312008	+0·094309
14·02	+0·224505	−0·241513	15·14	+0·310061	+0·100401
14·04	+0·229286	−0·236634	15·16	+0·307993	+0·106445
14·06	+0·233969	−0·231668	15·18	+0·305804	+0·112439
14·08	+0·238553	−0·226617	15·20	+0·303496	+0·118380
14·10	+0·243034	−0·221483	15·22	+0·301069	+0·124266
14·12	+0·247411	−0·216268	15·24	+0·298525	+0·130095
14·14	+0·251684	−0·210975	15·26	+0·295865	+0·135865
14·16	+0·255850	−0·205605	15·28	+0·293091	+0·141573
14·18	+0·259908	−0·200161	15·30	+0·290203	+0·147217
14·20	+0·263856	−0·194645	15·32	+0·287203	+0·152796
14·22	+0·267693	−0·189059	15·34	+0·284092	+0·158306
14·24	+0·271418	−0·183406	15·36	+0·280871	+0·163746
14·26	+0·275029	−0·177688	15·38	+0·277542	+0·169113
14·28	+0·278525	−0·171907	15·40	+0·274107	+0·174406
14·30	+0·281905	−0·166066	15·42	+0·270567	+0·179624
14·32	+0·285167	−0·160167	15·44	+0·266923	+0·184763
14·34	+0·288311	−0·154213	15·46	+0·263177	+0·189822
14·36	+0·291335	−0·148205	15·48	+0·259330	+0·194799
14·38	+0·294239	−0·142147	15·50	+0·255385	+0·199691
14·40	+0·297021	−0·136041			

The Neumann G Functions.

The Neumann Functions $G_n(x)$ of order greater than unity are of frequent occurrence in physical problems, such as the diffraction of light, pressure of radiation, &c. Tables of the functions have been found from those of $G_0(x)$ and $G_1(x)$ by (*a*) direct calculation and (*b*) logarithmic computation from the recurrence formula

$$G_{n+1}(x) = \frac{2n}{x} G_n(x) - G_{n-1}(x)$$

and verified in the case when x is an integer by the relation

$$J_n(x)\, G_{n+1}(x) - J_{n+1}(x)\, G_n(x) = \frac{1}{x}.$$

The Bessel Functions $J_n(x)$ for positive integral values of n and x have been given by Meissel for $x = 1$ to $x = 24$.

The Tables may be used to calculate $G_n(x)$ for other values of the argument x by employing the following formula:

$$G_n(x+h) = G_n(x) + h\left[\frac{n}{x} G_n(x) - G_{n+1}(x)\right] + \frac{h^2}{2!}\left[\left\{\frac{n(n-1)}{x^2} - 1\right\} G_n(x) + \frac{1}{x} G_{n+1}(x)\right] + \ldots$$

Tables of the Neumann Functions. $G_n(x)$.

$G_n(x)$	$x =$ 0·1	0·2	0·3	0·4	0·5
$n = 0$	+ 2·40998	+1·69820	+1·26806	+0·95194	+0·69825
1	+10·14570	+5·22105	+3·60200	+2·79739	+2·31138
2	—	—	—	—	+8·54729

$G_n(x)$	$x =$ 0·6	0·7	0·8	0·9	1·0
$n = 0$	+0·48461	+0·29950	+0·13635	−0·00884	−0·13863
1	+1·97982	+1·73298	+1·53647	+1·37150	+1·22713
2	+6·11479	+4·65188	+3·70481	+3·05663	+2·59289
3	—	—	—	—	+9·14442

$G_n(x)$	$x =$ 1·1	1·2	1·3	1·4	1·5
$n = 0$	−0·25473	−0·35827	−0·45009	−0·53076	−0·60075
1	+1·09660	+0·97568	+0·86161	+0·75264	+0·64765
2	+2·24855	+1·98440	+1·77565	+1·60597	+1·46429
3	+7·07994	+5·63900	+4·60192	+3·83584	+3·25711

$G_n(x)$	$x =$ 1·6	1·7	1·8	1·9	2·0
$n = 0$	−0·66041	−0·71004	−0·74995	−0·78040	−0·80170
1	+0·54597	+0·44725	+0·35133	+0·25825	+0·16813
2	+1·34287	+1·23622	+1·14032	+1·05224	+0·96982
3	+2·81121	+2·46149	+2·18271	+1·95700	+1·77152
4	+9·19916	+7·45141	+6·13537	+5·12776	+4·34473

Tables of the Neumann Functions. $G_n(x)$—continued.

$G_n(x)$	$x=$ 2·1	2·2	2·3	2·4	2·5
$n=0$	−0·81413	−0·81805	−0·81379	−0·80176	−0·78237
1	+0·08118	−0·00234	−0·08212	−0·15785	−0·22921
2	+0·89144	+0·81592	+0·74238	+0·67022	+0·59900
3	+1·61681	+1·48583	+1·37322	+1·27488	+1·18761
4	+3·72802	+3·23634	+2·83993	+2·51698	+2·25126
5	—	—	+8·50480	+7·11504	+6·01643

$G_n(x)$	$x=$ 2·6	2·7	2·8	2·9	3·0
$n=0$	−0·75607	−0·72336	−0·68474	−0·64075	−0·59195
1	−0·29588	−0·35756	−0·41398	−0·46486	−0·51000
2	+0·52847	+0·45849	+0·38904	+0·32015	+0·25196
3	+1·10891	+1·03682	+0·96974	+0·90645	+0·84594
4	+2·03056	+1·84554	+1·68899	+1·55526	+1·43992
5	+5·13897	+4·43145	+3·85593	+3·38393	+2·99385
6	—	—	—	—	+8·53959

$G_n(x)$	$x=$ 3·1	3·2	3·3	3·4	3·5
$n=0$	−0·53894	−0·48232	−0·42269	−0·36068	−0·29692
1	−0·54920	−0·58231	−0·60924	−0·62991	−0·64432
2	+0·18462	+0·11837	+0·05345	−0·00986	−0·07127
3	+0·78742	+0·73028	+0·67403	+0·61832	+0·56287
4	+1·33942	+1·25090	+1·17206	+1·10100	+1·03619
5	+2·66914	+2·39697	+2·16732	+1·97228	+1·80557
6	+7·27071	+6·23963	+5·39557	+4·69982	+4·12257

$G_n(x)$	$x=$ 3·6	3·7	3·8	3·9	4·0
$n=0$	−0·23202	−0·16662	−0·10132	−0·03672	+0·02661
1	−0·65250	−0·65451	−0·65049	−0·64060	−0·62506
2	−0·13048	−0·18717	−0·24104	−0·29180	−0·33914
3	+0·50752	+0·45217	+0·39676	+0·34133	+0·28592
4	+0·97635	+0·92041	+0·86751	+0·81691	+0·76802
5	+1·66214	+1·53791	+1·42957	+1·33439	+1·25012
6	+3·64070	+3·23611	+2·89452	+2·60460	+2·35728
7	—	+8·95757	+7·71102	+6·67976	+5·82172

$G_n(x)$	$x=$ 4·1	4·2	4·3	4·4	4·5
$n=0$	+0·08811	+0·14726	+0·20357	+0·25657	+0·30584
1	−0·60412	−0·57807	−0·54726	−0·51203	−0·47281
2	−0·38281	−0·42254	−0·45811	−0·48931	−0·51598
3	+0·23065	+0·17566	+0·12111	+0·06721	+0·01416
4	+0·72034	+0·67348	+0·62710	+0·58095	+0·53486
5	+1·17490	+1·10715	+1·04558	+0·98908	+0·93670
6	+2·14526	+1·96260	+1·80449	+1·66694	+1·54669
7	+5·10391	+4·50029	+3·99020	+3·55714	+3·18781
8	—	—	—	+9·65122	+8·37095

Tables of the Neumann Functions. $G_n(x)$—continued.

$G_n(x)$	$x=$ 4·6	4·7	4·8	4·9	5·0
$n=0$	+0·35101	+0·39174	+0·42773	+0·45876	+0·48462
1	−0·43000	−0·38406	−0·33547	−0·28470	−0·23226
2	−0·53797	−0·55517	−0·56751	−0·57496	−0·57752
3	−0·03780	−0·08842	−0·13746	−0·18466	−0·22976
4	+0·48866	+0·44229	+0·39569	+0·34885	+0·30182
5	+0·88765	+0·84125	+0·79694	+0·75421	+0·71266
6	+1·44101	+1·34761	+1·26460	+1·19036	+1·12351
7	+2·87150	+2·59946	+2·36457	+2·16095	+1·98376
8	+7·29834	+6·39546	+5·63205	+4·98377	+4·43101

$G_n(x)$	$x=$ 5·1	5·2	5·3	5·4	5·5
$n=0$	+0·50517	+0·52033	+0·53005	+0·53433	+0·53325
1	−0·17866	−0·12439	−0·06998	−0·01591	+0·03732
2	−0·57523	−0·56817	−0·55645	−0·54023	−0·51968
3	−0·27251	−0·31266	−0·34999	−0·38426	−0·41527
4	+0·25464	+0·20741	+0·16024	+0·11327	+0·06666
5	+0·67194	+0·63175	+0·59186	+0·55207	+0·51223
6	+1·06289	+1·00750	+0·95647	+0·90908	+0·86467
7	+1·82897	+1·69324	+1·57374	+1·46811	+1·37432
8	+3·95783	+3·55123	+3·20058	+2·89712	+2·63361
9	—	+9·23362	+8·08839	+7·11596	+6·28707

$G_n(x)$	$x=$ 5·6	5·7	5·8	5·9	6·0
$n=0$	+0·52691	+0·51547	+0·49911	+0·47810	+0·45270
1	+0·08923	+0·13937	+0·18729	+0·23260	+0·27491
2	−0·49505	−0·46657	−0·43453	−0·39925	−0·36106
3	−0·44283	−0·46678	−0·48697	−0·50328	−0·51561
4	+0·02058	−0·02478	−0·06923	−0·11256	−0·15455
5	+0·47224	+0·43200	+0·39148	+0·35066	+0·30954
6	+0·82270	+0·78268	+0·74419	+0·70689	+0·67046
7	+1·29069	+1·21574	+1·14823	+1·08709	+1·03137
8	+2·40402	+2·20335	+2·02740	+1·87264	+1·73607
9	+5·57794	+4·96911	+4·44461	+3·99125	+3·59816
10	—	—	—	—	+9·05841

$G_n(x)$	$x=$ 6·5	7·0	7·5	8·0	8·5
$n=0$	+0·27213	+0·04076	−0·18428	−0·35111	−0·42444
1	+0·43054	+0·47543	+0·40704	+0·24828	+0·04111
2	−0·13965	+0·09507	+0·29282	+0·41318	+0·43411
3	−0·51648	−0·42110	−0·25087	−0·04169	+0·16318
4	−0·33710	−0·45602	−0·49351	−0·44445	−0·31892
5	+0·10159	−0·10006	−0·27555	−0·40275	−0·46334
6	+0·49339	+0·31307	+0·12612	−0·05900	−0·22619
7	+0·80929	+0·63676	+0·47734	+0·31426	+0·14402
8	+1·24969	+0·96044	+0·76491	+0·60895	+0·46340
9	+2·26687	+1·55854	+1·15447	+0·90364	+0·72826
10	+5·02780	+3·04723	+2·00582	+1·42424	+1·07879
11	—	+7·14782	+4·19437	+2·65697	+1·81008
12	—	—	—	+5·88241	+3·60612
13	—	—	—	—	+8·37191

Tables of the Neumann Functions. $G_n(x)$—continued.

$G_n(x)$	$x=$ 9·0	9·5	10·0	10·5	11·0
$n=0$	−0·39260	−0·26894	−0·08745	+0·10608	+0·26522
1	−0·16386	−0·31915	−0·39115	−0·36710	−0·25715
2	+0·35619	+0·20175	+0·00922	−0·17600	−0·31198
3	+0·32216	+0·40410	+0·39484	+0·30005	+0·14370
4	−0·14141	+0·05347	+0·22769	+0·34746	+0·39036
5	−0·44786	−0·35907	−0·21269	−0·03532	+0·14020
6	−0·35621	−0·43144	−0·44038	−0·38110	−0·26291
7	−0·02709	−0·18591	−0·31576	−0·40022	−0·42701
8	+0·31408	+0·15747	−0·00169	−0·15253	−0·28056
9	+0·58544	+0·45112	+0·31306	+0·16780	+0·01893
10	+0·85681	+0·69729	+0·56519	+0·44018	+0·31153
11	+1·31859	+1·01685	+0·81733	+0·67064	+0·54749
12	+2·36640	+1·65753	+1·23293	+0·96497	+0·78344
13	+4·99180	+3·17058	+2·14171	+1·53501	+1·16185

$G_n(x)$	$x=$ 11·5	12·0	12·5	13·0	13·5
$n=0$	+0·35379	+0·35380	+0·26894	+0·12285	−0·04724
1	−0·09102	+0·08969	+0·24165	+0·33000	+0·33619
2	−0·36962	−0·33885	−0·23028	−0·07208	+0·09705
3	−0·03755	−0·20264	−0·31534	−0·35217	−0·30743
4	+0·35003	+0·23753	+0·07892	−0·09046	−0·23369
5	+0·28105	+0·36100	+0·36584	+0·29651	+0·16895
6	−0·10564	+0·06330	+0·21370	+0·31854	+0·35883
7	−0·39128	−0·29770	−0·16064	−0·00247	+0·15001
8	−0·37070	−0·41061	−0·39367	−0·32120	−0·20326
9	−0·12448	−0·24979	−0·34326	−0·39285	−0·39092
10	+0·17587	+0·03593	−0·10063	−0·22275	−0·31796
11	+0·43034	+0·30968	+0·18226	+0·05016	−0·08013
12	+0·64738	+0·53181	+0·42140	+0·30763	+0·18737
13	+0·92073	+0·75304	+0·62684	+0·51778	+0·41324

$G_n(x)$	$x=$ 14·0	14·5	15·0	15·5	16·0
$n=0$	−0·19979	−0·29893	−0·32274	−0·26805	−0·15050
1	+0·26177	+0·12730	−0·03310	−0·18031	−0·27956
2	+0·23719	+0·31648	+0·31833	+0·24478	+0·11555
3	−0·19400	−0·03999	+0·11799	+0·24348	+0·30845
4	−0·32033	−0·33303	−0·27113	−0·15053	+0·00012
5	+0·01095	−0·14375	−0·26259	−0·32117	−0·30839
6	+0·32815	+0·23390	+0·09607	−0·05667	−0·19286
7	+0·27032	+0·33732	+0·33945	+0·27730	+0·16375
8	−0·05783	+0·09179	+0·22075	+0·30713	+0·33614
9	−0·33641	−0·23603	−0·10398	+0·03975	+0·17239
10	−0·37470	−0·38480	−0·34553	−0·26098	−0·14220
11	−0·19887	−0·29472	−0·35672	−0·37649	−0·35014
12	+0·06218	−0·06237	−0·17766	−0·27340	−0·33925
13	+0·30548	+0·19149	+0·07246	−0·04683	−0·15873

Bessel Functions of Half-integral Order.

The solution of the equation

$$\frac{d^2u_n}{dx^2} + \left\{1 - \frac{n(n+1)}{x^2}\right\}u_n = 0$$

being taken in the symbolical form

$$u_n = x^{n+1}\left(-\frac{1}{x}\frac{d}{dx}\right)^n \frac{Ae^{-ix} + Be^{+}}{x}$$

yields as standard functions of real quantities

$$S_n(x) = x^{n+1}\left(-\frac{1}{x}\frac{d}{dx}\right)^n \frac{\sin x}{x}$$

$$C_n(x) = x^{n+1}\left(-\frac{1}{x}\frac{d}{dx}\right)^n \frac{\cos x}{x},$$

with $$E_n(x) = x^{n+1}\left(-\frac{1}{x}\frac{d}{dx}\right)^n \frac{e^{-ix}}{x} = C_n(x) - i\,S_n(x)$$

as an important associated function.

The functions $(E_n(x))^2 = (S_n(x))^2 + (C_n(x))^2$

$$(E_n'(x))^2 = (S_n'(x))^2 + (C_n'(x))^2$$

are of importance, and have been tabulated with $S_n(x)$, $C_n(x)$, and their derivatives $S_n'(x)$, $C_n'(x)$.

The connection with Bessel Functions is apparent from the differential equation, giving

$$S_n(x) = \sqrt{\tfrac{1}{2}\pi x}\, J_{n+\frac{1}{2}}(x)$$
$$C_n(x) = (-1)^n\sqrt{\tfrac{1}{2}\pi(x)}\, J_{-n-\frac{1}{2}}(x).$$

From the differential equation, we obtain

$$S_n'(x) = \frac{n+1}{x}S_n(x) - S_{n+1}(x)$$

$$S_n'(x) = S_{n-1}(x) - \frac{n}{x}S_n(x)$$

with corresponding formulæ for $C_n'(x)$, $E_n'(x)$.

By elimination of $S_n'(x)$, we get the recurrence formula

$$S_{n+1}(x) = \frac{2n+1}{x}S_n(x) - S_{n-1}(x).$$

Bessel Functions of Half-integral Order.

n	$S_n(1)$	$C_n(1)$	$[E_n(1)]^2$	n
0	·8414710	·5403023	1·0	0
1	·3011687	1·3817733	2·0	1
2	·0620351	3·605018	13·0	2
3	·0090066	16·64331	277·0	3
4	·0010110	112·8982		
5	·0000926	999·4403		
6	·0000072	10880·95		
7	·0000005	140452·8		

n	$S_n'(1)$	$C_n'(1)$	$[E_n'(1)]^2$	n
0	·5403023	−·8414710	1·0	0
1	·5403023	−·8414710	1·0	1
2	·1770986	−5·828262	34·0	2
3	·0350153	−46·32493	2146·0	3
4	·0049625	−434·9494		
5	·0005482	−4884·304		
6	·0000496	−64286·23		
7	·0000038	−972289·0		

n	Log. $[S_n(1)]$	Log. $[C_n(1)]$	Log. $[E_n(1)]^2$	n
0	$\bar{1}$·9250391	$\bar{1}$·7326368	·0000000	0
1	$\bar{1}$·4788098	·1404368	·3010300	1
2	$\bar{2}$·7926371	·5569074	1·1139434	2
3	$\bar{3}$·9545600	1·2212399	2·4424798	3
4	$\bar{3}$·0047580	2·0526860		

n	Log. $[S_n'(1)]$	Log. $[C_n'(1)]$	Log. $[E_n'(1)]^2$	n
0	$\bar{1}$·7326368	$\bar{1}$·9250391	·0000000	0
1	$\bar{1}$·7326368	$\bar{1}$·9250391	·0000000	1
2	$\bar{1}$·2482150	·7055390	1·5314789	2
3	$\bar{2}$·5442579	1·6658147	3·3316297	3
4	$\bar{3}$·6957021	2·6384387		

n	$S_n(2)$	$C_n(2)$	$[E_n(2)]^2$	n
0	·9092974	−·4161468	1·000000	0
1	·8707955	·7012240	1·250000	1
2	·3968959	1·4679828	2·312500	2
3	·1214442	2·968733	8·828125	3
4	·0281588	8·922583	79·61328	4
5	·0052703	37·18289	1382·567	5
6	·0008281	195·5833		
7	·0001122	1234·109		
8	·0000134	9060·232		
9	·0000014	75777·86		
10	·0000001	710829·4		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(2)$	$C_n'(2)$	$[E_n'(2)]^2$	n
0	−·4161468	−·9092974	1·0000000	0
1	·4738997	−·7667588	·8125000	1
2	·4738997	−·7667588	·8125000	2
3	·2147296	−2·985117	8·957031	3
4	·0651266	−14·87643	221·3125	4
5	·0149829	−84·03464	7061·821	5
6	·0027861	−549·5671		
7	·0004354	−4123·797		
8	·0000587	−35006·82		
9	·0000070	−331940·1		
10	·0000007	−3478369·		

n	Log. $[S_n(2)]$	Log. $[C_n(2)]$	Log. $[E_n(2)]^2$	n
0	$\bar{1}$·9587060	$\bar{1}$·6192466	·0000000	0
1	$\bar{1}$·9399162	$\bar{1}$·8458568	·0969100	1
2	$\bar{1}$·5986767	·1667210	·3640817	2
3	$\bar{1}$·0843767	·4725711	·9458684	3
4	$\bar{2}$·4496139	·9504906	1·9009855	4
5	$\bar{3}$·7218386	1·5703431	3·1406862	5
6	$\bar{4}$·9180733	2·2913318		

n	Log. $[S_n'(2)]$	Log. $[C_n'(2)]$	Log. $[E_n'(2)]^2$	n
0	$\bar{1}$·6192466	$\bar{1}$·9587060	·0000000	0
1	$\bar{1}$·6756864	$\bar{1}$·8846588	$\bar{1}$·9098234	1
2	$\bar{1}$·6756864	$\bar{1}$·8846588	$\bar{1}$·9098234	2
3	$\bar{1}$·3318919	·4749613	·9521642	3
4	$\bar{2}$·8137585	1·1724988	2·3450059	4
5	$\bar{2}$·1755970	1·9244583	3·8489167	5
6	$\bar{3}$·4449957	2·7400207		

n	$S_n(3)$	$C_n(3)$	$[E_n(3)]^2$	n
0	·1411200	−·9899925	1·0000000	0
1	1·0370325	−·1888775	1·1111111	1
2	·8959125	·8011150	1·4444444	2
3	·4561550	1·5240692	2·530864	3
4	·1684491	2·755046	7·618656	4
5	·0491924	6·741070	45·44444	5
6	·0119231	21·96221	482·3389	6
7	·0024745	88·42851		
8	·0004495	420·1803		
9	·0000726	2292·593		
10	·0000106	14099·58		
11	·0000014	96404·45		
12	·0000002	725001·2		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(3)$	$C_n'(3)$	$[E_n'(3)]^2$	n
0	—·9899925	—·1411200	1·0000000	0
1	—·2045575	—·9270333	·9012346	1
2	·4397575	—·7229542	·7160494	2
3	·4397575	—·7229542	·7160494	3
4	·2315561	—2·149326	4·673220	4
5	·0864617	—8·480070	71·91907	5
6	·0253460	—37·18335	1382·602	6
7	·0061492	—184·3710		
8	·0012759	—1032·052		
9	·0002316	—6457·600		
10	·0000374	—44705·00		
11	·0000054	—339383·4		
12	·0000007	—2803600·		

n	Log. $[S_n(3)]$	Log. $[C_n(3)]$	Log. $[E_n(3)]^2$	n
0	$\bar{1}$·1495886	$\bar{1}$·9956319	·0000000	0
1	·0157924	$\bar{1}$·2761801	·0457574	1
2	$\bar{1}$·9522636	1·9036949	·1597008	2
3	$\bar{1}$·6591125	·1830046	·4032688	3
4	$\bar{1}$·2264687	·4401289	·8818784	4
5	$\bar{2}$·6918984	·8287288	1·6574808	5
6	$\bar{2}$·0763909	1·3416761	2·6833523	6
7	$\bar{3}$·3934926	1·9465923		

n	Log. $[S_n'(3)]$	Log $[C_n'(3)]$	Log. $(E_n'(3))^2$	n
0	$\bar{1}$·9956319	$\bar{1}$·1495886	·0000000	0
1	$\bar{1}$·3108155	$\bar{1}$·9670954	$\bar{1}$·9548378	1
2	$\bar{1}$·6432133	$\bar{1}$·8591108	$\bar{1}$·8549430	2
3	$\bar{1}$·6432133	$\bar{1}$·8591108	$\bar{1}$·8549430	3
4	$\bar{1}$·3646563	·3323022	·6696163	4
5	$\bar{2}$·9368240	·9283995	1·8568440	5
6	$\bar{2}$·4039119	1·5703485	3·1406973	6
7	$\bar{3}$·7888217	2·2656927		

n	$S_n(4)$	$C_n(4)$	$[E_n(4)]^2$	n
0	—·7568025	—·6536436	1·0000000	0
1	·4644430	—·9202134	1·0625000	1
2	1·1051347	—·0365164	1·2226562	2
3	·9169754	·8745679	1·6057129	3
4	·4995723	1·5670102	2·705093	4
5	·2070622	2·6512051	7·071763	5
6	·0698487	5·7238037	32·76681	6
7	·0199460	15·95116	254·4398	7
8	·0049490	54·09304	2926·056	8
9	·0010870	213·9442		
10	·0002144	962·1421		
11	·0000384	4837·302		
12	·0000063	26852·34		
13	·0000009	162989·8		
14	·0000001	1072329·		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(4)$	$C_n'(4)$	$[E_n'(4)]^2$	n
0	—·6536436	+·7568025	1·0000000	0
1	—·8729132	—·4235903	·9414062	1
2	—·0881244	—·9019552	·8212891	2
3	·4174032	—·6924423	·6537018	3
4	·4174032	—·6924423	·6537018	4
5	·2407446	—1·746996	3·109954	5
6	·1022891	—5·934501	35·22876	6
7	·0349431	—22·19072	492·4293	7
8	·0100481	—92·23491	8507·279	8
9	·0025032	—427·2815		
10	·0005511	—2191·411		
11	·0001088	—12340·44		
12	·0000195	—75719·73		
13	·0000032	—502864·7		
14	·0000005	—3593662·		

n	Log. $[S_n(4)]$	Log. $[C_n(4)]$	Log. $[E_n(4)]^2$	n
0	$\bar{1}$·8789825	$\bar{1}$·8153410	·0000000	0
1	$\bar{1}$·6669324	$\bar{1}$·9638885	·0263289	1
2	0·0434153	$\bar{2}$·5624884	·0873043	2
3	$\bar{1}$·9623577	$\bar{1}$·9417935	·2056678	3
4	$\bar{1}$·6985983	0·1950719	·4321823	4
5	$\bar{1}$·3161007	·4234433	·8495276	5
6	$\bar{2}$·8441582	·7576848	1·5154341	6
7	$\bar{2}$·2998566	1·2027922	2·4055851	7
8	$\bar{3}$·6945133	1·7331414	3·4662827	8
9	$\bar{3}$·0362346	2·3303006		

n	Log. $[S_n(4)]$	Log. $[C_n'(4)]$	Log. $[(E_n'(4)]^2$	n
0	$\bar{1}$·8153410	$\bar{1}$·8789825	0·0000000	0
1	$\bar{1}$·9409711	$\bar{1}$·6269460	1·9737771	1
2	$\bar{2}$·9450960	$\bar{1}$·9551850	$\bar{1}$·9144960	2
3	$\bar{1}$·6205557	$\bar{1}$·8403836	$\bar{1}$·8153797	3
4	$\bar{1}$·6205557	$\bar{1}$·8403836	$\bar{1}$·8153797	4
5	$\bar{1}$·3815565	·2422918	·4927540	5
6	$\bar{1}$·0098296	·7733841	1·5468972	6
7	$\bar{2}$·5433616	1·3461714	2·6923439	7
8	$\bar{2}$·0020852	1·9648953	3·9297907	8
9	$\bar{3}$·3984910	2·6307141		

Bessel Functions of Half-integral Order—continued.

n	$S_n(5)$	$C_n(5)$	$[E_n(5)]^2$	n
0	—·9589243	·2836622	1·0000000	0
1	—·4754470	—·9021918	1·0400000	1
2	·6736561	—·8249773	1·1344000	2
3	1·1491031	·0772145	1·3263999	3
4	·9350883	·9330777	1·7450241	4
5	·5340558	1·6023252	2·852662	5
6	·2398345	2·592038	6·776181	6
7	·0895139	5·136973	26·39650	7
8	·0287072	12·81888	164·3244	8
9	·0080905	38·44722		
10	·0020367	133·2806		
11	·0004637	521·3312		
12	·0000964	2264·843		
13	·0000185	10802·88		
14	·0000033	56071·73		
15	·0000005	314413·1		
16	·0000001	1893290·		

n	$S_n'(5)$	$C_n'(5)$	$[E'(5_n)]^2$	n
0	·2836622	·9589243	1·0000000	0
1	—·8638349	·4641006	·9616000	1
2	—·7449095	—·5722009	·8823040	2
3	—·0158058	—·8713060	·7594240	3
4	·4010325	—·6692476	·6087194	4
5	·4010325	—·6692476	·6087194	5
6	·2462544	—1·5081202	2·335068	6
7	·1145151	—4·599725	21·17059	7
8	·0435824	—15·37324	236·3383	8
9	·0141443	—56·38612		
10	·0040171	—228·1139		
11	·0010165	—1013·648		
12	·0002323	—4912·292		
13	·0000484	—25823·65		
14	·0000093	—146197·9		
15	·0000017	—887167·7		
16	·0000003	—5744114·		

n	Log. $[S_n(5)]$	Log. $[C_n(5)]$	Log. $[E_n(5)]^2$	n
0	$\bar{1}$·9817843	$\bar{1}$·4528015	·0000000	0
1	$\bar{1}$·6771021	$\bar{1}$·9552980	·0170333	1
2	$\bar{1}$·8284378	$\bar{1}$·9164420	·0547662	2
3	·0603589	$\bar{2}$·8876992	·1226745	3
4	$\bar{1}$·9708527	$\bar{1}$·9699178	·2418014	4
5	$\bar{1}$·7275867	·2047506	·4552503	5
6	$\bar{1}$·3799116	·4136413	·8309850	6
7	$\bar{2}$·9518904	·7107073	1·4215464	7
8	$\bar{2}$·4579904	1·1078501	2·2157021	8
9	$\bar{3}$·9079754	1·5848650		
10	$\bar{3}$·3089316	2·1247668		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n'(5)]$	Log. $[C_n'(5)]$	Log. $[E_n'(5)]^2$	n
0	$\bar{1}$·4528015	$\bar{1}$·9817843	·0000000	0
1	$\bar{1}$·9364307	$\bar{1}$·6660121	$\bar{1}$·9829945	1
2	$\bar{1}$·8721035	$\bar{1}$·7575486	$\bar{1}$·9456183	2
3	$\bar{2}$·1988166	$\bar{1}$·9401707	$\bar{1}$·8804846	3
4	$\bar{1}$·6031796	$\bar{1}$·8255868	$\bar{1}$·7844172	4
5	$\bar{1}$·6031796	$\bar{1}$·8255868	$\bar{1}$·7844172	5
6	$\bar{1}$·3913840	·1784359	·3682996	6
7	$\bar{1}$·0588626	·6627318	1·3257329	7
8	$\bar{2}$·6393112	1·1867653	2·3735342	8
9	$\bar{2}$·1505807	1·7511723		
10	$\bar{3}$·6039080	2·3581517		

n	$S_n(6)$	$C_n(6)$	$[E_n(6)]^2$	n
0	−·2794155	·9601703	1·0000000	0
1	−1·0067395	−·1193871	1·0277778	1
2	−·2239543	−1·0198638	1·0902778	2
3	·8201110	−·7304994	1·2062114	3
4	1·1807504	·1676145	1·4222661	4
5	·9510146	·9819212	1·8685981	5
6	·5627764	1·6325743	2·982016	6
7	·2683343	2·5553232	6·601680	7
8	·1080593	4·755734	22·62868	8
9	·0378337	10·91926	119·2316	9
10	·0117474	29·82191	889·3466	10
11	·0032822	93·45743		
12	·0008345	328·4316		
13	·0001948	1275·007		
14	·0000420	5409·102		
15	·0000084	24868·98		
16	·0000016	123080·6		
17	·0000003	652074·6		

n	$S_n'(6)$	$C_n'(6)$	$[E_n'(6)]^2$	n
0	·9601703	·2794155	1·0000000	0
1	−·1116256	·9800681	·9729938	1
2	−·9320881	·2205675	·9174383	2
3	−·6340098	−·6546141	·8304880	3
4	·0329440	−·8422424	·7104576	4
5	·3882382	−·6506531	·5740783	5
6	·3882382	−·6506531	·5740783	6
7	·2497198	−1·3486361	1·8811792	7
8	·1242552	−3·785655	14·34662	8
9	·0513087	−11·62315	135·1002	9
10	·0182547	−38·78393	1504·193	10
11	·0057300	−141·5167		
12	·0016133	−563·4057		
13	·0004125	−2434·084		
14	·0000967	−11346·23		
15	·0000197	−56763·36		
16	·0000040	−303346·1		
17	·0000008	−1833143·		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n(6)]$	Log. $[C_n(6)]$	Log. $[E_n(6)]^2$	n
0	$\bar{1}$·4462504	$\bar{1}$·9823482	·0000000	0
1	·0029172	$\bar{1}$·0769574	·0118993	1
2	$\bar{1}$·3501593	·0085422	·0375371	2
3	$\bar{1}$·9138726	$\bar{1}$·8636199	·0814234	3
4	·0721581	$\bar{1}$·2243116	·1529808	4
5	$\bar{1}$·9781872	$\bar{1}$·9920766	·2715159	5
6	$\bar{1}$·7503359	·2128730	·4745099	6
7	$\bar{1}$·4286762	·4074458	·8196545	7
8	$\bar{1}$·0336621	·6772176	1·3546592	8
9	$\bar{2}$·5778788	1·0381930	2·0763912	9
10	$\bar{2}$·0699421	1·4745354	2·9490710	10
11	$\bar{3}$·5161693	1·9706139	3·9412276	11

n	Log. $[S_n'(6)]$	Log. $[C_n'(6)]$	Log. $[E_n'(6)]^2$	n
0	$\bar{1}$·9823482	$\bar{1}$·4462504	·0000000	0
1	$\bar{1}$·0477638	$\bar{1}$·9912562	$\bar{1}$·9881101	1
2	$\bar{1}$·9694570	$\bar{1}$·3435416	$\bar{1}$·9625768	2
3	$\bar{1}$·8020960	$\bar{1}$·8159854	$\bar{1}$·9193334	3
4	$\bar{2}$·5177768	$\bar{1}$·9254370	$\bar{1}$·8515380	4
5	$\bar{1}$·5390982	1·8133495	$\bar{1}$·7589712	5
6	$\bar{1}$·5890982	$\bar{1}$·8133495	$\bar{1}$·7589712	6
7	$\bar{1}$·3974530	·1298948	·2744302	7
8	$\bar{1}$·0943146	·5781411	1·1567497	8
9	$\bar{2}$·7101914	1·0653238	2·1306561	9
10	$\bar{2}$·2613742	1·5886518	3·1773036	10
11	$\bar{3}$·7581532	2·1508077		

n	$S_n(7)$	C(7)	$[E_n(7)]^2$	n
0	·6569866	·7539023	1·0000000	0
1	—·6600470	·7646869	1·0204082	1
2	—·9398639	—·4261793	1·0649730	2
3	—·0112843	—1·0691007	1·1431036	3
4	·9285796	—·6429214	1·2756080	4
5	1·2051723	·2424875	1·5112406	5
6	·9652627	1·0239731	1·9802530	6
7	·5874584	1·6591769	3·097975	7
8	·2935767	2·531406	6·494203	8
9	·1255135	4·488523	20·16258	9
10	·0471029	9·651729	93·15808	10
11	·0157952	24·46666	598·6178	11
12	·0047955	70·73873		
13	·0013317	228·1717		
14	·0003410	809·3520		
15	·0000811	3124·858		
16	·0000180	13029·31		
17	·0000037	58299·01		
18	·0000007	278465·7		
19	·0000001	1413591·		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(7)$	$C_n'(7)$	$[E_n'(7)]^2$	n
0	·7539023	−·6569866	1·0000000	0
1	·7512790	+·6446613	·9800082	1
2	−·3915145	+·8864524	·9390815	2
3	−·9350278	+·0320067	·8753014	3
4	−·5419012	−·7017170	·7860638	4
5	·0677422	−·8161267	·6706518	5
6	·3778043	−·6352038	·5462200	6
7	·3778043	−·6352038	·5462200	7
8	·2519422	−1·2338585	1·585882	8
9	·1322021	−3·239553	10·51218	9
10	·0582237	−9·299661	86·48708	10
11	·0222819	−28·79588	829·2033	11
12	·0075743	−96·79974		
13	·0023224	−353·0087		
14	·0006497	−1390·532		
15	·0001673	−5886·773		
16	·0000400	−26656·41		
17	·0000089	−128544·0		
18	·0000019	−657755·8		
19	·0000004	−3558425·		

n	Log. $[S_n(7)]$	Log. $[C_n(7)]$	Log $[E_n(7)]^2$	n
0	$\bar{1}$·8175564	$\bar{1}$·8773150	·0000000	0
1	$\bar{1}$·8195749	$\bar{1}$·8834836	·0087739	1
2	$\bar{1}$·9730650	$\bar{1}$·6295924	·0273386	2
3	$\bar{2}$·0524737	·0290186	·0580857	3
4	$\bar{1}$·9678191	$\bar{1}$·8081579	·1057172	4
5	·0810491	$\bar{1}$·3846893	·1793337	5
6	$\bar{1}$ 9846455	·0102885	·2967208	6
7	$\bar{1}$·7689771	·2198927	·4910780	7
8	$\bar{1}$·4677215	·4033618	·8125259	8
9	$\bar{1}$·0986904	·6521034	1·3045461	9
10	$\bar{2}$·6730476	·9846051	1·9692206	10
11	$\bar{2}$·1985243	1·3885748	2·7771497	11
12	$\bar{3}$·6808361	1·8496573		
13	$\bar{3}$·1244043	2·3582617		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n'(7)]$	Log. $[C_n'(7)]$	Log. $[E_n'(7)]^2$	n
0	$\bar{1}\cdot8773150$	$\bar{1}\cdot8175364$	·0000000	0
1	$\bar{1}\cdot8758012$	$\bar{1}\cdot8093316$	$\bar{1}\cdot9912297$	1
2	$\bar{1}\cdot5927478$	1·9476554	$\bar{1}\cdot9727033$	2
3	$\bar{1}\cdot9708245$	$\bar{2}\cdot5052413$	$\bar{1}\cdot9421576$	3
4	$\bar{1}\cdot7339202$	$\bar{1}\cdot8461593$	$\bar{1}\cdot8954578$	4
5	$\bar{2}\cdot8308592$	$\bar{1}\cdot9117576$	$\bar{1}\cdot8264970$	5
6	$\bar{1}\cdot5772670$	$\bar{1}\cdot8029131$	$\bar{1}\cdot7373676$	6
7	1·5772670	$\bar{1}\cdot8029131$	$\bar{1}\cdot7373676$	7
8	$\bar{1}\cdot4013009$	·0912654	·2002709	8
9	$\bar{1}\cdot1212385$	·5104850	1·0216928	9
10	$\bar{2}\cdot7650977$	·9684671	1·9369512	10
11	$\bar{2}\cdot3479526$	1·4593304	2·9186610	11
12	3·8793411	1·9858742		
13	$\bar{3}\cdot3659326$	2·5477854		

n	$S_n(8)$	$C_n(8)$	$[E_n(8)]^2$	n
0	·9893582	−·1455000	1·0000000	0
1	·2691698	·9711707	1·0156250	1
2	−·8884196	·5096891	1·0490725	2
3	−·8244320	−·6526151	1·1055944	3
4	·1670415	−1·0807273	1·1958744	4
5	1·0123538	−·5632031	1·3420578	5
6	1·2249449	·3063230	1·5943238	6
7	·9781817	1·0609780	2·082514	7
8	·6091458	1·6830107	3·203583	8
9	·3162531	2·515420	6·427352	9
10	·1419553	4·291111	18·43378	10
11	·0563796	8·748747	76·54376	11
12	·0201360	20·86154	435·2041	12
13	·0065454	56·44356		
14	·0019547	169·6355		
15	·0005403	558·4850		
16	·0001391	1994·494		
17	·0000335	7668·802		
18	·0000076	31556·52		
19	·0000016	138280·1		
20	·0000003	642558·9		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(8)$	$C_n'(8)$	$[E_n'(8)]^2$	n
0	−·1455000	−·9893582	1·0000000	0
1	·9557120	−·2668964	·9846190	1
2	·4912747	·8437485	·9532622	2
3	−·5792575	·7544197	·9046883	3
4	−·9079528	−·1122515	·8369787	4
5	−·4656796	−·7287253	·7478982	5
6	·0936451	−·7929453	·6375318	6
7	·3690359	−·6220327	·5231121	7
8	·3690359	−·6220327	·5231121	8
9	·2533611	−1·1468365	1·379426	9
10	·1388090	−2·848469	8·133044	10
11	·0644334	−7·738416	59·88724	11
12	·0261760	−22·54356	508·2127	12
13	·0094997	−70·85924		
14	·0031247	−240·4185		
15	·0009416	−877·5239		
16	·0002621	−3430·503		
17	·0000679	−14301·71		
18	·0000165	−63333·36		
19	·0000038	−296858·7		
20	·0000008	−1468117·		

n	Log. $[S_n(8)]$	Log. $[C_n(8)]$	Log. $[E_n(8)]$	n
0	$\bar{1}$·9953536	$\bar{1}$·1628630	0·0000000	0
1	$\bar{1}$·4300263	$\bar{1}$·9872956	·0067334	1
2	$\bar{1}$·9486181	$\bar{1}$·7073053	·0208055	2
3	$\bar{1}$·9161549	$\bar{1}$·8146570	·0435958	3
4	$\bar{1}$·2228244	·0337162	·0776855	4
5	·0053323	$\bar{1}$·7506650	·1277712	5
6	·0881165	$\bar{1}$·4861797	·2025765	6
7	$\bar{1}$·9904195	·0257063	·3185878	7
8	$\bar{1}$·7847213	·2260868	·5056360	8
9	$\bar{1}$·5000347	·4006105	·8080321	9
10	$\bar{1}$·1521516	·6325697	1·2656145	10
11	$\bar{2}$·7511219	·9419459	1·8839098	11
12	$\bar{2}$·3039729	1·3193463	2·6386930	12
13	$\bar{3}$·8159352	1·7516144		
14	$\bar{3}$·2910760	2·2295167		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n'(8)]$	Log. $[C_n'(9)]$	Log. $[E_n'(8)]^2$	n
0	$\bar{1}$·1628630	$\bar{1}$·9953536	·0000000	0
1	$\bar{1}$·9803270	$\bar{1}$·4263426	$\bar{1}$·9932682	1
2	$\bar{1}$·6913243	$\bar{1}$·9262130	$\bar{1}$·9792124	2
3	$\bar{1}$·7628717	$\bar{1}$·8776130	$\bar{1}$·9564990	3
4	*$\bar{1}$·9580633*	$\bar{1}$·0501919	$\bar{1}$·9227145	4
5	$\bar{1}$·6680872	$\bar{1}$·8625639	$\bar{1}$·8738424	5
6	$\bar{2}$·9714850	$\bar{1}$·8992433	$\bar{1}$·8045018	6
7	$\bar{1}$·5670687	$\bar{1}$·7938132	$\bar{1}$·7185048	7
8	$\bar{1}$·5670687	$\bar{1}$·7938132	$\bar{1}$·7185948	8
9	$\bar{1}$·4037399	·0595015	0·1396984	9
10	$\bar{1}$·1424175	·4546115	·9102531	10
11	$\bar{2}$·8091109	·8886521	1·7773344	11
12	$\bar{2}$·4178966	1·3530225	2·7060455	12
13	$\bar{3}$·9777117	1·8503964		
14	$\bar{3}$·4948071	2·3809678		

n	$S_n(9)$	$C_n(9)$	$[E_n(9)]^2$	n
0	·4121185	−·9111303	1·0000000	0
1	·9569212	·3108818	1·0123457	1
2	−·0931448	1·0147575	1·0384086	2
3	−1·0086683	·2528724	1·0813561	3
4	−·6913750	−·8180790	1·1472525	4
5	·3172933	−1·0709514	1·2476118	5
6	1·0791779	−·4908616	1·4055701	6
7	1·2415193	·3619291	1·6723628	7
8	·9900209	1·0940767	2·177146	8
9	·6285202	1·7046603	3·300904	9
10	·3368550	2·504651	6·386745	10
11	·1574749	4·139524	17·16046	11
12	·0655808	8·074134	65·19594	12
13	·0246941	18·28863	3344·745	13
14	·0085014	46·79174	21894·67	14
15	·0026992	132·4848		
16	·0007959	409·5447		
17	·0002192	1369·179		
18	·0000567	4915·041		
19	·0000138	18837·10		
20	·0000032	76712·39		
21	·0000007	330630·4		
22	·0000001	1502966·		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(9)$	$C\ '(9)$	$[E_n'(9)]^2$	n
0	−·9111303	−·4121185	1·0000000	0
1	·3057939	−·9456727	·9878066	1
2	·9776200	·0853801	·9630307	2
3	·2430780	·9304667	·9248551	3
4	−·7013905	·6164631	·8719753	4
5	−·8676491	−·2231060	·8025912	5
6	−·4021587	−·7437103	·7148366	6
7	·1135518	−·7723620	·6094370	7
8	·3615007	−·6105836	·5034950	8
9	·3615007	−·6105836	·5034950	9
10	·2542368	−1·0782848	1·227334	10
11	·1443857	−2·554768	6·547686	11
12	·0700338	−6·625988	43·90862	12
13	·0299116	−18·34277	336·4581	13
14	·0114697	−54·49853	2970·090	14
15	·0040027	−174·0162		
16	·0012842	−595·5946		
17	·0003818	−2176·682		
18	·0001059	−8460·902		
19	·0000275	−34852·17		
20	·0000068	−151634·87		
21	·0000016	−694758·6		
22	·0000003	−3343287·		

n	Log. $[S_n(9)]$	Log. $[C_n(9)]$	Log. $[E_n(9)]^2$	n
0	$\bar{1}$·6150221	$\bar{1}$·9595804	0·0000000	0
1	$\bar{1}$·9808761	$\bar{1}$·4925953	·0053288	1
2	$\bar{2}$·9691584	·0063623	·0163683	2
3	·0037484	1·4029014	·0339688	3
4	$\bar{1}$·8397137	$\bar{1}$·9127952	·0596590	4
5	$\bar{1}$·5014608	·0297698	·0960795	5
6	·0330930	$\bar{1}$·6909590	·1478524	6
7	·0939534	$\bar{1}$·5586235	·2233305	7
8	$\bar{1}$·9956444	·0390477	·3378876	8
9	$\bar{1}$·7983192	·2316378	·5186329	9
10	$\bar{1}$·5274431	·3987471	·8052796	10
11	$\bar{1}$·1972113	·6169504	1·2345289	11
12	$\bar{2}$·8167769	·9070959	1·8142206	12
13	$\bar{2}$·3925925	1·2621811	2·5243630	13
14	$\bar{3}$·9294886	1·6701692	3·3403384	14
15	$\bar{3}$·4312382	2·1221659		
16	$\bar{4}$·9008836	2·6123012		

Bessel Functions of Half-integral Order—continued.

n	Log. [$S_n'(9)$]	Log. [$C_n'(9)$]	Log. [$E_n'(9)$]^2	n
0	$\bar{1}$·9595804	$\bar{1}$·6150221	·0000000	0
1	$\bar{1}$·4854289	$\bar{1}$·9757408	$\bar{1}$·9946719	1
2	$\bar{1}$·9901701	$\bar{2}$·9313568	$\bar{1}$·9836401	2
3	$\bar{1}$·3857457	$\bar{1}$·9687008	$\bar{1}$·9660737	3
4	1·8459599	1·7899070	$\bar{1}$·9405042	4
5	1·9383441	$\bar{1}$·3485112	$\bar{1}$·9044943	5
6	1·6043974	$\bar{1}$·8714038	$\bar{1}$·8542069	6
7	1·0551940	$\bar{1}$·8878209	$\bar{1}$·7849288	7
8	$\bar{1}$·5581092	$\bar{1}$·7857452	$\bar{1}$·7019951	8
9	$\bar{1}$·5581092	$\bar{1}$·7857452	$\bar{1}$·7019951	9
10	$\bar{1}$·4052385	·0327335	·0889627	10
11	$\bar{1}$·1595242	·4073515	·8160879	11
12	$\bar{2}$·8453076	·8212507	1·6425498	12
13	$\bar{2}$·4758399	1·2634649	2·5269309	13
14	$\bar{2}$·0595528	1·7363848		
15	3·6023493	2·2405896		
16	3·1086340	2·7749508		

n	S (10)	$C_n(10)$	[E_n (10)]^2	n
0	—·5440211	—·8390715	1·0000000	0
1	·7846694	—·6279283	1·0100000	1
2	·7794219	·6506930	1·0309000	2
3	—·3949584	·9532748	1·0647250	3
4	—1·0558929	·0165993	1·1151852	4
5	—·5553451	—·9383354	1·1888816	5
6	·4450132	—1·0487683	1·2979516	6
7	1·1338623	—·4250633	1·4663225	7
8	1·2557802	·4111733	1·7460475	8
9	1·0009641	1·1240579	2·265235	9
10	·6460515	1·7245367	3·391409	10
11	·3557441	2·497469	6·363907	11
12	·1721600	4·019643	16·18716	12
13	·0746558	7·551637	57·03279	13
14	·0294108	16·36978	267·9704	14
15	·0106354	39·92072	1593·663	15
16	·0035590	107·3844		
17	·0011094	314·4480		
18	·0003239	993·1834		
19	·0000890	3360·331		
20	·0000231	12112·11		
21	·0000057	46299·30		
22	·0000013	186974·9		
23	·0000003	795087·8		

Bessel Functions of Half-integral Order—continued.

n	$S_n'(10)$	$C\ '(10)$	$[E_n'(10)]^2$	n
0	−·8390715	·5440211	1·0000000	0
1	−·6224881	−·7762787	·9901000	1
2	·6287850	−·7580669	·9700360	2
3	·8979095	·3647106	·9392552	3
4	·0273987	·9466351	·8968684	4
5	−·7782203	·4857670	·8415964	5
6	−·8223531	−·3090745	·7717916	6
7	−·3486904	−·7512239	·6859223	7
8	·1292381	−·7540019	·5852213	8
9	·3549126	−·6004788	·4865378	9
10	·3549126	−·6004788	·4865378	10
11	·2547330	−1·0226794	1·110762	11
12	·1491522	−2·326102	5·432996	12
13	·0751074	−5·797486	33·61647	13
14	·0334867	−15·36605	236·1167	14
15	·0134576	−43·51130	1893·233	15
16	·0049410	−131·8944		
17	·0016730	−427·1771		
18	·0005264	−1473·282		
19	·0001549	−5391·445		
20	·0000428	−20863·88		
21	·0000112	−85116·43		
22	·0000028	−365045·5		
23	·0000007	−1641727·		

n	Log. $[S_n(10)]$	Log. $[C_n(10)]$	Log. $[E_n(10)]^2$	n
0	$\bar{1}$·7356158	$\bar{1}$·9237990	·0000000	0
1	$\bar{1}$·8946867	$\bar{1}$·7979100	·0043214	1
2	1·8917726	$\bar{1}$·8133761	·0132165	2
3	$\bar{1}$·5965514	$\bar{1}$·9792181	·0272375	3
4	0·0236199	$\bar{2}$·2200898	·0473370	4
5	$\bar{1}$·7445630	$\bar{1}$·9723581	·0751386	5
6	$\bar{1}$·6483729	0·0206795	·1132584	6
7	·0545604	$\bar{1}$·6284536	·1662294	7
8	·0989136	$\bar{1}$·6140292	·2420560	8
9	·0004185	0·0507886	·3551134	9
10	$\bar{1}$·8102671	0·2366724	·5303798	10
11	1·5511378	0·3975001	·8037238	11
12	$\bar{1}$·2359323	0·6041873	1·2091707	12
13	$\bar{2}$·8730639	0·8780411	1·7561246	13
14	$\bar{2}$·4685065	1·2140428	2·4280865	14
15	$\bar{2}$·0267549	1·6011983	3·2023961	15
16	3·5513330	2·0309414		
17	$\bar{3}$·0450910	2·4975488		

Bessel Functions of Half-integral Order—continued.

n	Log. $[S_n'(10)]$	Log. $[C_n'(10)]$	Log. $[E_n'(10)]^2$	n
0	$\bar{1}\cdot9237990$	$\bar{1}\cdot7356158$	$\cdot0000000$	0
1	$\bar{1}\cdot7941311$	$\bar{1}\cdot8900177$	$\bar{1}\cdot9956791$	1
2	$\bar{1}\cdot7985024$	$\bar{1}\cdot8797075$	$\bar{1}\cdot9867879$	2
3	$\bar{1}\cdot9532326$	$\bar{1}\cdot5619484$	$\bar{1}\cdot9727835$	3
4	$\bar{2}\cdot4377299$	$\bar{1}\cdot9761826$	$\bar{1}\cdot9527289$	4
5	$\bar{1}\cdot8911026$	$\bar{1}\cdot6864279$	$\bar{1}\cdot9251039$	5
6	$\bar{1}\cdot9150583$	$\bar{1}\cdot4900631$	$\bar{1}\cdot8875001$	6
7	$\bar{1}\cdot5424400$	$\bar{1}\cdot8757693$	$\bar{1}\cdot8362748$	7
8	$\bar{1}\cdot1113905$	$\bar{1}\cdot8773724$	$\bar{1}\cdot7673201$	8
9	$\bar{1}\cdot5501214$	$\bar{1}\cdot7784977$	$\bar{1}\cdot6871163$	9
10	$\bar{1}\cdot5501214$	$\bar{1}\cdot7784977$	$\bar{1}\cdot6871163$	10
11	$\bar{1}\cdot4060852$	$0\cdot0097396$	$\cdot0456210$	11
12	$\bar{1}\cdot1736296$	$\cdot3666287$	$\cdot7350394$	12
13	$\bar{2}\cdot8756827$	$\cdot7632397$	$1\cdot5265521$	13
14	$\bar{2}\cdot5247951$	$1\cdot1865623$	$2\cdot3731267$	14
15	$\bar{2}\cdot1289691$	$1\cdot6386021$	$3\cdot2772041$	15
16	$\bar{3}\cdot6938116$	$2\cdot1202264$		
17	$\bar{3}\cdot2235085$	$2\cdot6306079$		

Binary Canon.—Report of the Committee, consisting of Lt.-Col. ALLAN CUNNINGHAM, R.E. (*Chairman*), Prof. A. E. H. LOVE (*Secretary*), *and* Major P. A. MACMAHON, *appointed for Disposing of Copies of the Binary Canon by presentation to Mathematical Societies.*

THE Committee have sent out fifty-eight copies of the above work to representative Mathematical Societies at home and abroad (thirteen and forty-five respectively) at a cost of 4*l.* 9*s.*, as per enclosed account, and return now the unexpended balance of eleven shillings.

Dynamic Isomerism.—Report of the Committee, consisting of Professor H. E. ARMSTRONG (*Chairman*), Dr. T. M. LOWRY (*Secretary*), Professor SYDNEY YOUNG, Dr. C. H. DESCH, Dr. J. J. DOBBIE, *and* Dr. M. O. FORSTER. (*Drawn up by the Secretary.*)

Anomalous Rotatory Dispersion.

DURING the year much justification has been found for the view expressed in the Report presented at Birmingham 'that a knowledge of the phenomena of dynamic isomerism is essential for the interpretation of optical rotation, especially in the case of liquids which show anomalous rotatory dispersion,' and that 'the study of rotatory

dispersion will open up a new and fruitful field for the investigation of dynamic isomerism.' The importance of this aspect of the subject is shown by the conspicuous part which it played in a general discussion on 'Optical Rotatory Power,' held before the Faraday Society on March 27, 1914, to which the Chairman and Secretary of this Committee contributed papers. Preliminary experiments, which will be described in a subsequent Report, have shown (1) that ethyl tartrate, the typical example of anomalous rotatory dispersion, is probably a mixture, and (2) that nitrocamphor, the typical example of dynamic isomerism, gives rise to anomalous rotatory dispersion in certain solvents.

Dynamic Isomerism, Metamerism, Tautomerism, and Desmotropy.

Attention has recently been directed (*Proc. Chem. Soc.*, April 4, 1914) to the importance of maintaining strict accuracy in the use of terms to describe the phenomena of reversible isomeric change.

Briefly, it may be said that all the essential facts in reference to the conception of *equilibrium between isomerides* are set out in Butlerow's classical, but almost forgotten, paper, 'Ueber Isodibutylen' (*Annalen*, 1877, **189**, 44). The name *dynamic isomerism* was introduced in 1899 (*Trans. Chem. Soc.*, **75**, 235) as a paraphrase of Butlerow's description of 'a condition of equilibrium depending on incessant isomeric change'; but the adjective *isodynamic* had already been suggested by Armstrong in 1889 (*Watts' Dictionary*, 'Isomerism') to describe those isomerides 'which change their type with exceptional facility in the course of chemical interchanges.' The word *metameric* had been used in this sense in 1833 by Berzelius to describe isomerides which were readily converted into one another, but the usefulness of the word was destroyed by a misguided attempt to transfer it to another usage.

The hypothesis of *tautomerism* was introduced by Laar in 1885 (*Ber.* **18**, 648; **19**, 730) to account for the facts which had already (as time has shown) been explained adequately by Butlerow. Laar asserts that, in every case of tautomerism, the different formulæ suggested by the reactions of the substance represent, 'not isomeric, but identical bodies'; the term cannot, therefore, be applied to any case of isomerism, however readily the isomerides may be converted into one another.

It is impossible to say whether tautomerism exists; but it has at least been proved by the work of Knorr that the two substances represented by the formulæ

$$CH_3{\cdot}CO{\cdot}CH_2{\cdot}CO_2Et \text{ and } CH_3{\cdot}C(OH){:}CH{\cdot}CO_2Et$$

are not tautomeric, but have a real existence as well-defined isomeric compounds, which only change into one another under definite physical and chemical conditions.

The word *desmotropy* was introduced by Jacobson (*Ber.* 1887, **20**, 1732, footnote; 1888, **21**, 2628, footnote) in 1887, when it had become evident that Laar's theory of tautomerism had broken down in the very case to which it had been most frequently applied, namely, the labile isomerism which results from the contiguity of a double bond and an acidic hydrogen atom. Jacobson considered 'that the known

forms of such compounds are to be represented by a definite grouping of atoms, which in certain reactions passes over into an isomeric grouping by a rearrangement of bonds consequent upon the displacement of a hydrogen atom'; it was to express this view that the word 'desmotropy' was introduced. If used in this sense, to describe the labile isomerism produced by the mobility of a hydrogen atom, it might be of real value; unfortunately the meaning of the word was tampered with by Hantzsch and Hermann (*Ber.* 1887, **20**, 2802), and, as an inevitable consequence, it has become ambiguous, and has ceased to be clearly significant.

Nearly all the cases to which the word 'tautomerism' has been misapplied in recent years are examples of isomerism pure and simple, the only special feature being the fact that the isomerides can be converted into one another with greater or less ease. It is therefore very rarely necessary to use any other words than 'isomerism' and 'isomeric change' to describe the phenomena. Isomeric compounds which owe their lability to a mobile hydrogen atom might well be distinguished as 'desmotropic' but for the ambiguity arising from the ill-advised action of Hantzsch in attempting to extend the meaning of this term. At the present time the least ambiguous phrase that can be used to distinguish ethyl acetoacetate and its allies from the very much larger group of substances which exhibit 'dynamic isomerism' or reversible isomeric change is to refer to them as examples of 'keto-enol' isomerism, and in other cases to use some similar specific name, describing the nature of the two compounds between which a condition of equilibrium may exist.

Isomeric Halogen-derivatives of Camphor.

Another fruitful, though expensive, line of research has been opened out during the year by applying the process of dynamic isomerism to the preparation of new halogen-derivatives of camphor. A new isomeride has been prepared from α-chlorocamphor by acting on it with alkali, in order to produce a condition of dynamic isomerism in the liquid, and then arresting the isomeric change by the addition of acid. On freezing the alcoholic solution, most of the original substance crystallises out, and the mother-liquor contains the isomeric α-chlorocamphor. This melts at 117° (instead of 94°) and has $[\alpha]_D + 41°$ (instead of +97°). As the new compound can be prepared readily on a large scale, it promises to be of great value in studying the type of dynamic isomerism in which a catalytic agent must be added deliberately in order to bring about a condition of equilibrium between isomers. The whole series of compounds which is now under investigation will provide valuable data for the study of dynamic isomerism and rotatory dispersion, and for the elucidation of the crystallographic structure of the camphor molecule.

The Committee asks for reappointment with a grant of £40. An increased grant is asked for to cover the heavy cost of the organic preparations referred to in the last section of the Report.

The Transformation of Aromatic Nitroamines and Allied Substances, and its Relation to Substitution in Benzene Derivatives.—Report of the Committee, consisting of Professor F. S. KIPPING (*Chairman*), Professor K. J. P. ORTON (*Secretary*), Dr. S. RUHEMANN, *and* Dr. J. T. HEWITT.

The Acetylation of Anilines by Acetic Anhydride in the presence of Catalysts.

(With W. H. GRAY, M.Sc.)

THE accelerating action of catalysts on the interaction of acetic anhydride and hydroxy- groups has long been known: it was first observed by Franchimont[1] in the acetylation of cellulose, and was later noted by numerous observers.[2] That catalysts had a similar effect in the action of acetic anhydride on the amino-group seems, however, to have been overlooked until Smith and Orton[3] made the discovery that negatively di-ortho-substituted anilines, such as *s*-tribromoaniline, can be acetylated at great speed at the ordinary temperature in the presence of sulphuric and other acids.

Such anilines are particularly suitable for such an investigation as they react very slowly indeed with acetic anhydride at the ordinary temperature, and at higher temperature mainly yield diacetyl derivatives, $Ar\text{-}NAc_2$; in the presence of a catalyst at low temperatures they yield, on the other hand, the monoacetyl derivative. Anilines with one ortho- position unoccupied form monoacetyl derivatives with such extreme ease that the presence of an acid is of no advantage, but, on the contrary, inhibits the reaction, most probably by forming stable salts which do not react with acetic anhydride.

Such salts as sodium acetate have long been known as catalysts of the acetylation of phenols. We have found that various salts have a similar effect in the case of amines. Ferric salts are as pre-eminent in this capacity as in the bromination of acetic anhydride and other compounds, which we are investigating.

An early attempt (Smith and Orton, *loc. cit.*) to throw light on the mechanism of such catalyses, using *s*-tribromophenol, demonstrated that acids varied greatly in catalytic effect; that the change was a reaction of the second order; that the speed was proportional to the concentration of the catalyst.

To follow quantitatively the interaction of acetic anhydride and a di-ortho negatively substituted aniline has proved a very difficult matter. The small capacity for forming salts, which is an advantage in following the effect of acid catalysis on acetylation, is a barrier to the estimation of unchanged aniline by the diazo- method. Moreover, the slowness with which the anilide is hydrolysed equally prevents estimation of the extent of acetylation.

[1] *Compt. rend.*, 1879, **89**, 711.

[2] Skraup, *Monatsh.* 1898, **19**, 458; Freyss, *Bull. Soc. Ind. Mulhouse*, 1899, **44**; J. Thiele, *Ber.* 1898, **31**, 1249; O. Stillich, *Ber.* 1903, **36**, 3115; 1905, **38**, 124; J. Boeseken, *Recueil des Trav. Chim.*, 1911, **31**, 350.

[3] *Trans. Chem. Soc.* 1908, **93**, 1243; 1909, **95**, 1060.

A most excellent method has now been devised for determining the amount of unchanged aniline. This consists in stopping the reaction by adding anhydrous sodium acetate, equivalent to the acid catalyst, followed by some excess of an acetic acid solution of nitric acid. The aniline is rapidly and quantitatively converted into a nitroamine (Orton[4]; W. H. Gray[5]). The nitroamine is completely extracted from the diluted solution by shaking three times with chloroform, and its quantity measured by titration of its alcoholic solution with baryta. The composition of the system could also be checked by direct estimation of the remaining acetic anhydride by the method devised by Orton and M. G. Edwards,[6] and amplified by Orton and Marian Jones.[7] The amount of anhydride found at a given period of the reaction corresponded well with that calculated from the initial concentration on the assumption that the loss of anhydride was solely due to acetylation. The accuracy and the refinements of this method of analysing the system are mainly due to the exhaustive experiments of Mr. W. H. Gray[8] on the stability of nitric acid in acetic acid solution and allied problems. The error in the estimation of the nitroamine in an acetic acid solution is not above ¼ per cent., whilst the error in the determination of the aniline by conversion into nitroamine falls below 1 per cent.

The velocity coefficients for a reaction of the second order are remarkably constant, in spite of the complicated and intricate analyses by which they are obtained.

Illustrations of the results are given in the following table:—

Exp. A. Initial concentrations:—*s*-tribromoaniline, 0·04; acetic anhydride 0·04 × 3·83; H_2SO_4=M/363·8.

Time from mixing.	Percentage aniline acetylated.	K_{II}.
Min.		
41	17·52	0·031
86	31·5	0·030
146	48·14	0·031
240	69·92	0·037

Exp. B. *s*-tribromoaniline, 0·02; acetic anhydride, 0·02 × 7·08; H_2SO_4=M/363·8.

Min.		
66	38·19	0·053
157	69·65	0·069
283	90·05	0·064

Exp. C. *s*-tribromoaniline, 0·02; acetic anhydride, 0·02 × 7·08; H_2SO_4=M/727·6.

Min.		
40	17·25	0·032
87	28·55	0·026
142	40·3	0·025
240	61·3	0·028

Since in the presence of sulphuric acid the anhydride is immediately

[4] *Trans. Chem. Soc.* 1902, 81, 490.
[5] *Thesis submitted to the University of Wales*, 1914.
[6] *Trans. Chem. Soc.* 1911, 99, 1181.
[7] *Trans. Chem. Soc.* 1912, 101, 1716.
[8] *Loc. cit.*, and *Analyst*, 1912, 37, 303.

hydrolysed by water in the acetic acid medium, the initial concentration was arrived at by deducting an amount equivalent to the water from the anhydride used.

The experiments have led to some very interesting results:—

1. The reaction is of the second order; the value of the expression, $\frac{1}{t} \cdot \frac{x}{(a-x)}$, is approximately halved by doubling the dilution.

2. The speed is approximately proportional to the concentration of the catalyst when the concentrations of the aniline and anhydride are kept constant.

3. A very remarkable effect was produced by variation of the concentration of the aniline, when anhydride and catalyst are kept constant. It would be expected that the speed of acetylation would fall on decreasing the concentration of the aniline; on the contrary, however, the speed increases. A comparison of experiments A and B shows that on halving the concentration of the aniline the speed is roughly doubled. The most obvious explanation of the observation is that the acid catalyst is partly combined with the aniline. Such a balanced action would follow the equation of equilibrium:—

$$[\text{Aniline}]\,[H_2SO_4] = K\,[\text{anilinium salt}].$$

$$[H_2SO_4] = K\,\frac{[\text{anilinium salt}]}{[\text{aniline}]}.$$

Since the proportion of the acid, and therefore of the salt, is very small in comparison with that of the aniline in these systems, the concentration of the acid is roughly inversely proportional to that of the aniline. The concentration of the free acid (or perhaps acid salt) is the dominant factor in the reaction, and hence the effect (if there be one) of the decrease of the aniline is completely concealed. This suggestion is made more probable by the effect of simultaneous reduction of the concentration of both acid and aniline; the velocity of acetylation is scarcely changed (Exp. C). It appears, then, that the speed of acetylation is independent (within certain limits) of the concentrations of the acid and aniline, provided that these quantities remain in the same ratio.

The action of the catalyst probably lies, as has been frequently suggested, in producing an 'active modification' of the acetic anhydride, which alone reacts with the aniline. The evidence, so far as it goes, points to the reaction of the anhydride and catalyst being momentary, whilst that of the 'active' form and the aniline is a time reaction. Too much stress cannot be put upon the fact that the reaction was of the second order, for the excess of anhydride was considerable. The combination of the acid with the aniline, moreover, obscures the issue, and renders a decision difficult with an acid catalyst.

A complete account of this research will be published in one of the usual chemical journals.

The Study of Plant Enzymes, particularly with relation to Oxidation.—Third Report of the Committee, consisting of Mr. A. D. Hall (*Chairman*), Dr. E. F. Armstrong (*Secretary*), Professor H. E. Armstrong, Professor F. Keeble, *and* Dr. E. J. Russell.

Work is being continued along the lines indicated in former reports.

The further investigation of the distribution of oxydases (peroxydase) in the flowers of *Primula sinensis* has led to the discovery that in certain white-flowered races which breed true to whiteness the peroxydase has a definite zonal distribution. Such white-flowered races, when crossed with coloured forms, yield in the F_2 generation a certain number of plants having flowers which exhibit a colour pattern of a similar zonal character. Hence this pattern may be referred to a lack of uniformity in distribution of the peroxydase constituent of the colour-forming mechanism, not of the chromogen. This investigation has involved the study of a large number of plants of known genetic constitution and of their progeny; it may be expected that eventually it will throw light on the phenomena of flaking and colour pattern in flowers.

Concurrently with the study of the distribution of oxydases in plants, the occurrence of reductases has also been investigated, using this term as a general expression for substances which exert a reducing action. After many trials, partial success has been achieved by the discovery of agents indicative of such compounds, and evidence of the zonal distribution of reductases has been obtained.

A general summary of the bearing of chemical observations on genetic constitution and the relation of enzymes to colour inheritance in plants was given before the Linnean Society in March, when it was particularly pointed out that, in life, interaction takes place between substances in pairs, the one being oxidised and the other reduced. Consequently the same interaction is often recorded whether oxydase or reductase be indicated by the agent used. This conception materially simplifies the study of the oxidative changes in plants.

The formation of red pigments from yellow flowers by reduction and subsequent oxidation described in the last report has been further studied during the year. To elucidate the precise nature of the change by working with material of known structure, the experiments were extended to quercetin, which has been reduced under a variety of conditions. As a rule, colourless compounds are formed which become red on exposure to the air or on the addition of hydrogen peroxide. The problem has been investigated independently at Reading by A. E. Everest ('The Production of Anthocyanins and Anthocyanidins,' *Proc. Roy. Society*, 1914, 87 B. 144), who finds that the change from yellow to red may be effected by reduction alone, and that reduction takes place quite readily without the occurrence of hydrolysis. As Willstätter has now directed his attention to the chemical structure of the anthocyanic class of pigments, it is not proposed to continue the research in this direction.

A study has been made of the rate at which various carbohydrate solutions are able to decolourise methylene blue in alkaline solution,

as this method is of value in discriminating between glucose and fructose (compare Muster and Woker, *Pflügers Archiv*, 1913, **155**, 92). On adding a few drops of methylene blue to a freshly prepared solution containing one per cent. of the carbohydrate, together with half of one per cent. of solution of sodium hydroxide, the blue color is almost immediately discharged in presence of fructose, but only after a certain interval—15 minutes—by glucose. After standing, the glucose solution acts much more rapidly, whereas the fructose is less active than at first. Most probably the active agent is the enolic form common to both sugars; as Lobry de Bruyn was the first to show, this is formed from both by the action of alkali. The possibility of the formation of fructose from glucose and *vice versa* in this manner in the plant must not be overlooked. The methylene blue test has been applied to a number of carbohydrates, so as to compare their relative rates of enolisation. Indigo-blue solution, which changes from green to red, and finally to yellow, as it is reduced, is an equally sensitive agent. In all cases, agitation with air restores the colour; the colour is not destroyed in faintly acid solution.

The behaviour of lipase has been further studied during the year. It has been shown that synthesis takes place under the influence of the enzyme to the greatest extent in the absence of all but traces of water, and that the presence of even a small proportion of water greatly favours action in the reverse direction.[1]

In view of the presence of ammonia in the nodular growths appearing on the roots of Leguminosæ, it appeared probable that the enzyme urease would be found in these. It has been detected in the nodules from Lupins and a number of other Leguminosæ. Attempts to detect the enzyme in organisms cultivated from the nodules have thus far been attended with negative results.

Mr. Benjamin, working at the Hawkesbury Agricultural College, near Sydney, Australia, has detected urease in nodules from several Australian plants, including wattles; also on tubercles derived from the Cycad *Macrozamia spiralis*. He has found urease also in the seeds of *Abrus precatorius*.

Correlation of Crystalline Form with Molecular Structure.—Report of the Committee, consisting of Professor W. J. Pope *(Chairman)*, Professor H. E. Armstrong *(Secretary)*, Mr. W. Barlow and Professor W. P. Wynne.

The following communications have been made to the Royal Society during the year:—

Morphological Studies of Benzene Derivatives. V. The Correlation of Crystalline Form with Molecular Structure: A Verification of the Barlow-Pope Conception of Valency-Volume. By Henry E.

[1] *Proc. Roy. Soc.* 1914, Series B, 'Studies on Enzyme Action,' xxii., Lipase (iv.) 'The Correlation of Hydrolytic and Synthetic Activity,' by Henry E. Armstrong and H. W. Gosney.

ARMSTRONG, R. T. COLGATE and E. H. RODD. Proc. Roy. Soc., Series A, Vol. 90, pp. 111-173.

VI. Parasulphonic derivatives of Chloro-, Bromo-, Todo, and Cyano-benzene. By C. S. MUMMERY, B.Sc.

VII. The Correlation of the Forms of Crystals with their Molecular Structure and Orientation in a Magnetic Field in the Case of Hydrated Sulphonates of Dyad Metals. By HENRY E. ARMSTRONG and E. H. RODD.

In the first of these it is shown that the method of treatment *introduced* by Barlow and Pope is applicable to a large number of derivatives of benzenesulphochloride or bromide of the formula $C_6H_3R_2 . SO_2Cl$, R being an atom of halogen. When equivalence parameters are calculated from the axial ratios and the valency volume, in nearly thirty cases the values found of two of the parameters are all but identical with those of the corresponding parameters of benzene, the third parameter being increased by the same amount beyond the benzene value by the introduction of the sulphonic radicle. Hence it is to be supposed that the halogens have the same relative valency volume as hydrogen in all the compounds considered. Numerous other cases are quoted in support of the conception of valency introduced by Barlow and Pope.

In the second communication data are given for various derivatives of benzenesulphochloride containing but one atom of halogen. It is shown that these fall into line with the di-derivatives.

In the third attention is called to crystallographic peculiarities presented by substituted benzenesulphonates of dyad metals and a close relationship to corresponding toluenemephonates is established. The influence of water of crystallisation is considered.

Attention is specially directed also to the peculiar behaviour of certain isomorphous salts of iron, cobalt and nickel in the magnetic field. When suspended similarly in either of two axial directions, corresponding isomorphous iron and cobalt salts always act along crystallographic axes at right angles to each other. Nickel salts behave like cobalt salts when suspended in the one axial direction, like iron salts when suspended in the other. Apparently the difference in the behaviour of the various salts is to be referred to magnetic peculiarities in the metallic atoms.

Study of Solubility Phenomena.—Interim Report of the Committee, consisting of Professor H. E. ARMSTRONG (*Chairman*), Dr. J. VARGAS EYRE (*Secretary*), Dr. E. F. ARMSTRONG, Professor A. FINDLAY, Dr. T. M. LOWRY, *and* Professor W. J. POPE.

MUCH of the time since the appointment of this Committee has been devoted to setting up the required apparatus and getting it into working order in a new laboratory. Materials have been purified and work has been done to ascertain within what limits solubility determinations were trustworthy under the new conditions.

Preliminary trials have been made to ascertain the influence of isomeric alcohols on the solubility of salts in water at 25° C. Small differences have been observed in the precipitating effect of the butylic alcohols, and work is now in progress to determine the variations in solubility of the chlorides of potassium, sodium and ammonium brought about by the addition of small quantities of the isomeric propylic, butylic and amylic alcohols.

It is desired that the Committee be reappointed.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Mr. R. H. TIDDEMAN *(Chairman)*, Dr. A. R. DWERRYHOUSE *(Secretary)*, Dr. T. G. BONNEY, Mr. F. W. HARMER, Rev. S. N. HARRISON, Dr. J. HORNE, Mr. W. LOWER CARTER, Professor J. W. SOLLAS, *and* Messrs. W. HILL, J. W. STATHER, *and* J. H. MILTON.

THE Committee reports that owing, probably, to the early date of the meeting no lists of erratics have been contributed during the year, and in consequence no part of the grant has been expended.

The Committee seeks reappointment with a grant of *5l.*

The Preparation of a List of Characteristic Fossils.—Second Interim Report of the Committee, consisting of Professor P. F. KENDALL *(Chairman)*, Mr. W. LOWER CARTER *(Secretary)*, Mr. H. A. ALLEN, Professor W. S. BOULTON, Professor G. COLE, Dr. A. R. DWERRYHOUSE, Professors J. W. GREGORY, Sir T. H. HOLLAND, G. A. LEBOUR, *and* S. H. REYNOLDS, Dr. MARIE C. STOPES, Mr. COSMO JOHNS, Dr. J. E. MARR, Dr. A. VAUGHAN, Professor W. W. WATTS, Mr. H. WOODS, *and* Dr. A. SMITH WOODWARD, *appointed for the consideration thereof.*

No meeting of the Committee was held during the year, but numerous suggestions for a list of fossils were received. From these a provisional list was compiled by the Secretary, and uncorrected were printed and circulated. This provisional list, when revised, will, it is hoped, form the basis for the publication of an amended list of fossils next year. The Committee ask for reappointment with a grant of £10.

Geology of Ramsey Island, Pembrokeshire.—Final Report of the Committee, consisting of Dr. A. STRAHAN *(Chairman)*, Dr. HERBERT H. THOMAS *(Secretary)*, Mr. E. E. L. DIXON, Dr. J. W. EVANS, Mr. J. F. N. GREEN *and* Professor O. T. JONES.

THE Committee have to report that the grant made to them in 1913 to aid Mr. J. Pringle in continuing his researches in the west of Pembroke-

shire has been spent. They have also to report that the detailed mapping of the island has been completed. The examination of the rocks and fossils which have been collected will be proceeded with.

For the purpose of description the island can be divided conveniently into two areas—a northern area composed of Lingula Flags, Arenig mudstones and shales, Lower Llanvirn, and the intrusive mass of Carn Ysgubor; and a southern area of Lower Llanvirn shales with interbedded tuffs and rhyolites, and a thick mass of intrusive quartz-porphyry. To the latter area belongs the mass of rhyolitic and brecciated tuffs of Carn Llundain.

Northern Area.

Lingula Flags.—The Lingula Flags consist of bluish-grey flaggy, micaceous shales with ribs of hard grey close-grained sandstone, some of which reach a thickness of two feet. They occupy the headland of Trwyn Drain-du, and they extend eastwards to Bay Ogof Hên, while on the eastern side of the island they form the cliffs from the north-east corner to Road Uchaf. The Flags also occur in the headland to the south of Abermawr. They are highly fossiliferous, and yield *Lingulella davisi* in great abundance.

Arenig.—All the zones of the Arenig are present. The lowest beds are bluish-grey sandy mudstones and shales with *Ogygia selwyni*, *Orthis proava*, and *O. menapiæ*. They are confined to the north-east corner of the island, and are faulted against the Lingula Flags. The mudstones are followed by bluish-black shales belonging to the Extensus Zone, and are well displayed in the cliffs at Road Uchaf and Road Isaf. Similar shales belonging to the Hirundo Zone are present in Abermawr.

Lower Llanvirn.—The base of the Lower Llanvirn is seen only in the cliffs in Abermawr, where the shales of the Hirundo Zone are succeeded by a thick series of hard dark- and light-coloured tuffs of fine texture, which yield *Didymograptus bifidus* in their highest beds. The tuffs are followed by fossiliferous blue-black shales, but their full thickness is not seen in the northern area.

Intrusive Rocks.—Carn Ysgubor is formed of an intrusive mass of quartz-albite-diabase, which has invaded the sediments of Lower Llanvirn, Arenig, and Lingula Flags. A small intrusion occurs south of Abermawr, where Lingula Flags are in contact with a quartz-keratophyre.

Southern Area.

This area was described in the first report, in which it was shown to be composed of *D. bifidus* shales which had been invaded by a thick mass of quartz-porphyry. The shales, well displayed in the cliffs of Porth Llauog and Foel Fawr, are highly fossiliferous, and a large collection of graptolites has been made from them. They contain layers of coarse agglomeratic tuff, and at Foel Fawr pass upwards into thick beds of tuff which are conformably overlain by grey rhyolites. The tuffs and conglomerate on Carn Llundain belong to the same period of eruption.

The two points of interest, therefore, which were made the object of mapping the island have been successfully solved. It has been found that the so-called Tremadoc beds are Arenig sediments, and that they do not pass downwards into the Lingula Flags, but are brought against them by a fault; also that the rocks hitherto regarded as pre-Cambrian belong to a period of igneous activity that occurred in Lower Llanvirn, or even later, times.

It is hoped that the full description of the district will be completed this year, and it is the present intention of Mr. J. Pringle to communicate the results of his investigations to the Geological Society of London.

The Old Red Sandstone Rocks of Kiltorcan, Ireland.—Interim Report of Committee, consisting of Professor GRENVILLE COLE (*Chairman*), Professor T. JOHNSON (*Secretary*), Dr. J. W. EVANS, Dr. R. KIDSTON, *and* Dr. A. SMITH WOODWARD.

OWING to the early date at which this year's Report is required, and the absence of Professor Johnson at the Australian Meeting, it is impossible to utilise the funds available for field-work, which normally is carried on during the long vacation.

Your Committee asks for its reappointment, and for the renewal of the grant of 10*l*. not utilised in 1913-14, together with the unexpended balance of 9*l*. odd.

Two papers have been published during the past year:—T. Johnson: 1. *Ginkgophyllum Kiltorkense* sp. nov.; 2. *Bothrodendron Kiltorkense* Haught. sp., its Stigmaria and Cone ('Sci. Proc., R. Dublin Society,' vol. xiv.).

Stratigraphical Names.—Interim Report of the Committee, consisting of Dr. J. E. MARR (*Chairman*), Professor GRENVILLE COLE, Mr. BERNARD HOBSON, Dr. J. HORNE, Professor LEBOUR, Dr. A. STRAHAN, Professor W. W. WATTS, *and* Dr. F. A. BATHER (*Secretary*), *appointed to consider the preparation of a List of Stratigraphical Names used in the British Isles, in connection with the Lexicon of Stratigraphical Names in course of preparation by the International Geological Congress.*

AT its Meeting in Stockholm, 1910, the International Geological Congress appointed a Committee to produce a 'Lexique international de Stratigraphie.' The convener of this International Committee is Dr. Lukas Waagen, of Vienna, and the Secretary of the present Committee had the honour of being appointed representative of Great Britain.

Before the Meeting of the International Geological Congress in Toronto, 1913, various proposals were discussed by the members of

the International Committee, and a provisional Report was laid before the International Congress. Unfortunately neither Dr. Waagen nor Dr. Bather were able to attend the Congress in Toronto, and up to the date of writing they have received no official communication from the officers of the Congress. It is, however, understood that the Congress can grant no subvention to aid the work.

The situation, therefore, may be thus summarised:—The International Congress has appointed a Committee to produce a laborious and costly work of undoubted value to all interested in Geology and the allied sciences. There are no funds for this purpose. The details of the scheme, even if decided on at the Congress, are not yet known to the present Committee of the Association.

Consequently your Committee has been unable to take any steps, although some of its members have made note of stratigraphical names observed in the course of their ordinary work, and are prepared to continue this practice and eventually to place such material at the disposal of the International Committee. Your Committee is, however, well aware that the search for names must be conducted systematically, and it considers that funds will be needed to pay searchers and compilers. A grant is not asked for at present, merely because it is not yet possible to draw up a plan of operations.

The fact that this Report will be presented to the Association when meeting in Australia leads your Committee to point out that it has been appointed to consider names used in the British Isles, and that no provision has yet been made for the other constituents of the British Empire. As regards India, indeed, the work has been accomplished by Sir Thomas Holland and Mr. G. H. Tipper in their 'Indian Geological Terminology.'[1] But it is desirable that other Committees should be formed, and the present occasion seems appropriate for the establishment of one to deal with Australasia. Any such Committees would communicate directly with Dr. L. Waagen (K.k. geolog. Reichsanstalt, Wien).

Your Committee asks for its reappointment, for the present without a grant.

Fauna and Flora of the Trias of the Western Midlands.—Report of the Committee, consisting of Mr. G. Barrow (*Chairman*), Mr. L. J. Wills (*Secretary*), Dr. J. Humphreys, Mr. W. Campbell Smith, Mr. D. M. S. Watson, *and* Prof. W. W. Watts.

This Committee regrets that owing to the early date at which the report has to be submitted this year, very slight progress has been made with the digging operations in Warwickshire and Worcestershire. Some hundred and more specimens have been obtained from the Arden Sandstone at Shelfield, near Alcester, and Hunt End, near

[1] *Mem. Geol. Surv. India*, vol xliii., Part 1, 1913.

Redditch, including the bones and teeth of *Labyrinthodon*, teeth of *Polyacrodus* and *Phœbodus* (?), plant remains, &c.

Permission has already been obtained to work in the famous Coton End Quarry at Warwick, and arrangements made for further digging at Shelfield should the grant be renewed. It is felt that the chief difficulty is the discovery of productive fossiliferous horizons, and then the arrangement for labour in scattered and often secluded localities. The larger part of the money so far spent has been in travelling expenses in this connection.

The Lower Palæozoic Rocks of England and Wales.—Report of the Committee, consisting of Prof. W. W. Watts *(Chairman)*, Prof. W. G. Fearnsides *(Secretary)*, Prof. W. S. Boulton, Mr. E. S. Cobbold, Mr. V. C. Illing, Dr. C. Lapworth, *and* Dr. J. E. Marr, *appointed to excavate Critical Sections therein.*

Nuneaton Area.—Mr. V. C. Illing reports that during the winter of 1913-14 and the ensuing spring, systematic trenching was begun across the outcrop of the Abbey Shale division of the Stockingford Shales. By the kind permission of Mr. Phillips, of Ansley Hall, the work was carried out in the Hartshill Hayes. A trench, thirty yards long, two feet wide, and three feet deep, was made in the direction of the dip of the shales, and cross trenches were cut along the strike of nine of the beds richest in fossils. In some cases these latter trenches were cut to a depth of ten feet. About thirty yards away, in the direction of the strike, a second trench was cut across the outcrop, and, in addition to the discovery of further types of fossils, evidence was obtained of lateral changes in lithology. Some five thousand specimens were obtained, chiefly of trilobites, ranging over some fifty different species. These indicate a fauna corresponding to that of the Upper Solva Beds and the Lower and Middle Menevian Beds, *i.e.* the zones of *Conocoryphe exsulans*, *Agnostus parvifrons*, *Conocoryphe æqualis* (?), and *Paradoxides davidis*, of Sweden, and the zones of *P. aurora*, *P. hicksii*, and *P. davidis*, of South Wales. In addition new links have been found between the fauna of this area and that of the corresponding beds in Bohemia, three of the forms being new to Britain. The fossils are being described and photographed, and a paper on the subject will be presented to the Geological Society.

Comley Area, Shropshire.—Mr. E. S. Cobbold reports that excavations have been begun in the Cambrian Rocks of the Comley area, but no report of the results is yet possible.

The Committee asks for reappointment with a grant of 15*l.*, which would include the unspent portion of this year's grant.

The Upper Old Red Sandstone of Dura Den.—Report of the Committee, consisting of Dr. J. Horne *(Chairman)*, Dr. T. J. Jehu *(Secretary)*, Mr. H. Bolton, Mr. A. W. R. Don, Dr. J. S. Flett, Dr. B. N. Peach, *and* Dr. A. Smith Woodward, *appointed to conduct the further exploration thereof; with a separate report by* Dr. Smith Woodward *on the Fish Remains.*

Since the preliminary report was presented at the Birmingham Meeting the excavations for fossil fishes at Dura Den have been completed and the ground has been levelled. The Committee desire again to acknowledge the courtesy of Mr. Bayne-Meldrum, of Balmungo, the proprietor, who gave great facilities for carrying out the operations. They wish also to express their obligations to Mr. R Dunlop, from Dunfermline, who superintended the work on the spot and who took a series of excellent photographs of the best specimens of fossil fishes.

At the outset brief reference may be made to the geological structure of the ground near Dura Den. Strata of Upper Old Red Sandstone age underlie the long depression of the Howe of Fife, which ranges westwards from St. Andrews Bay, between the slopes of the Ochil Hills on the north and the heights of the Carboniferous rocks with their intrusive masses on the south. The actual junction with the Lower Old Red Sandstone volcanic series of the Ochils is hidden everywhere by drift, but the line of contact is evidently an unconformable one. For the sheets of andesite dip south-east at angles of about 15°, and are overlapped at different horizons by the more gently inclined members of the Upper Old Red Sandstone.

In Central Fife there is a conformable passage from the Upper Old Red Sandstone into the Lower Carboniferous strata. But in Eastern Fife the top of the Upper Old Red Sandstone is cut off by a fault which crosses Dura Den in a north-easterly direction and brings down the Carboniferous strata on the south-east side.

The ravine of Dura Den has been cut by the Ceres Burn since the Ice Age. This rivulet is formed by the union of a number of smaller streams which rise in the Carboniferous area of Fife. The Den has been excavated across the line of fracture and is about a mile and a half in length (see Fig. 1).

Below the mouth of the Den the Ceres Burn enters the alluvial plain of the Eden and joins that river about a mile above the village of Dairsie. Dura Den is eroded in the Lower Carboniferous and Upper Old Red Sandstone formations. For a distance of several hundred yards the Upper Old Red Sandstone strata are laid bare in the channel of the stream and in a range of picturesque cliffs on either side. The section runs along the strike of nearly horizontal beds, so that only a comparatively small thickness of rocks is exposed. These belong to the upper part of the formation, but the actual top, as already

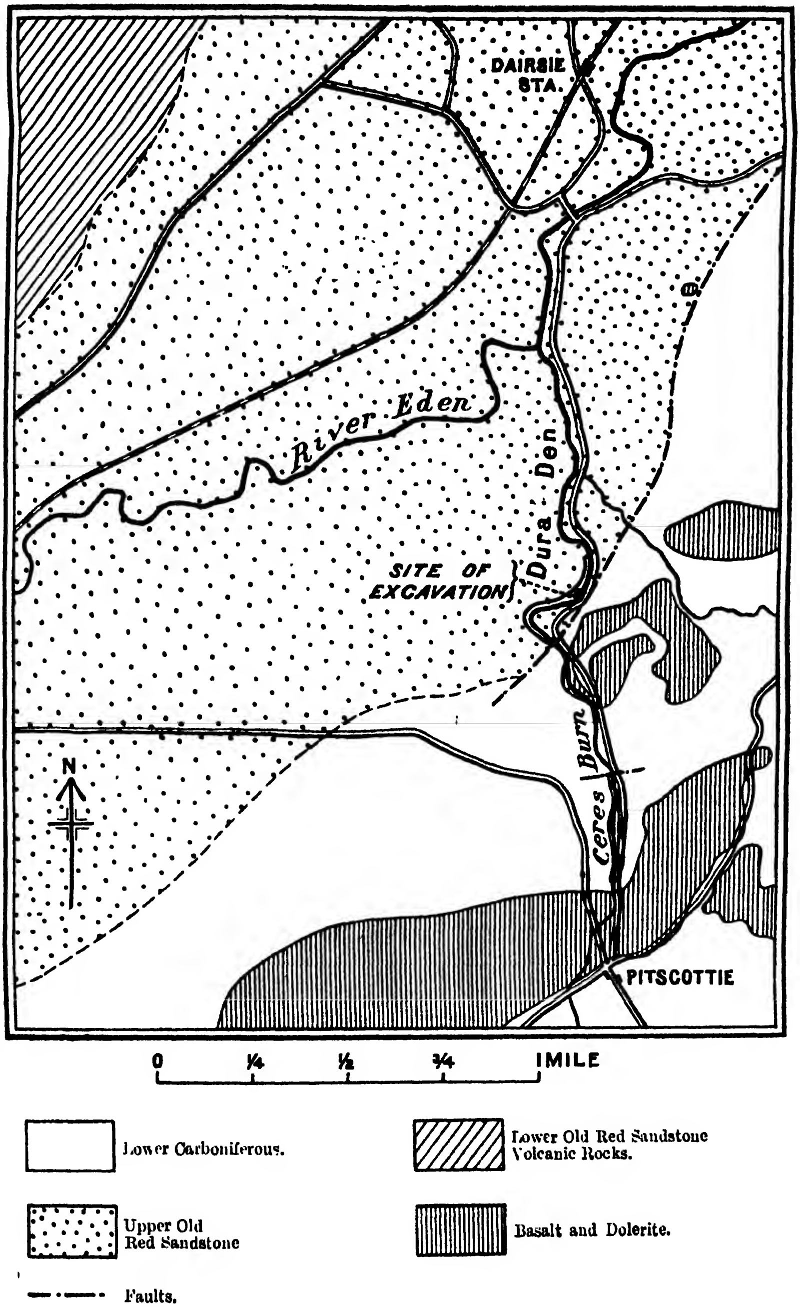


FIG. 1.—Geological Sketch-map of the District surrounding Dura Den.

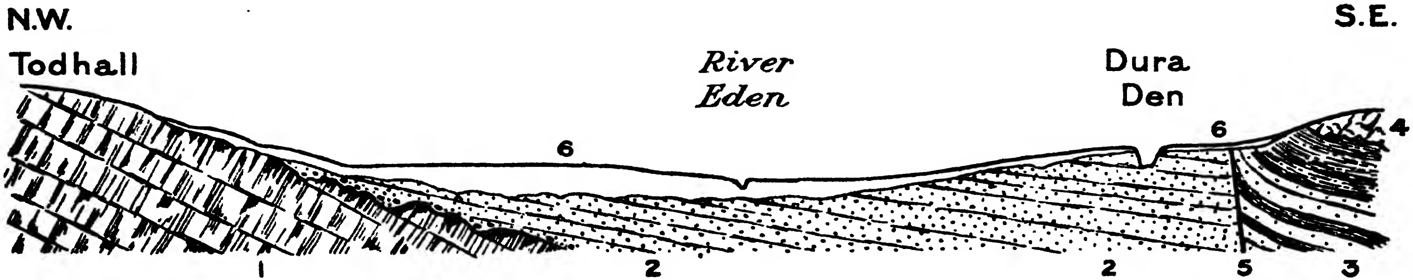


FIG. 2.—Section across the valley of the Eden from Todhall to Dura Den showing the relations of the strata (after Sir A. Geikie).

1. Volcanic Series of Lower Old Red Sandstone.
2. Red and Yellow Sandstones and Conglomerate of Upper Old Red Sandstone age.
3. Lower Carboniferous Series. 4. Intrusive Dolerite. 5. Fault. 6. Superficial Deposits.

indicated, is cut off by the fault, near which the Lower Carboniferous strata are seen dipping at angles of 35° to 40° to the south-east. The rocks consist of yellow, red, and greenish sandstones, with bands of clay or marl, and are nearly horizontal. They are rather fine-grained, somewhat fissile, and, in places, extremely false-bedded.

Remains of fishes in the Upper Old Red Sandstone of Fife were first observed in 1831 at Drumdryan, near Cupar, by the Rev. John Fleming. The scales detected by him were found to occur more abundantly at Dura Den, a mile farther east, and entire fishes were obtained there, preserved in the sandstone.

For years the Rev. Dr. Anderson worked at these beds and published numerous papers descriptive of the region. The fish-remains obtained from time to time at this famous locality were examined and described by Agassiz, Huxley, and other investigators. The excavations were carried on partly under the guidance of a Committee of the British Association, which gave its first report in 1860.

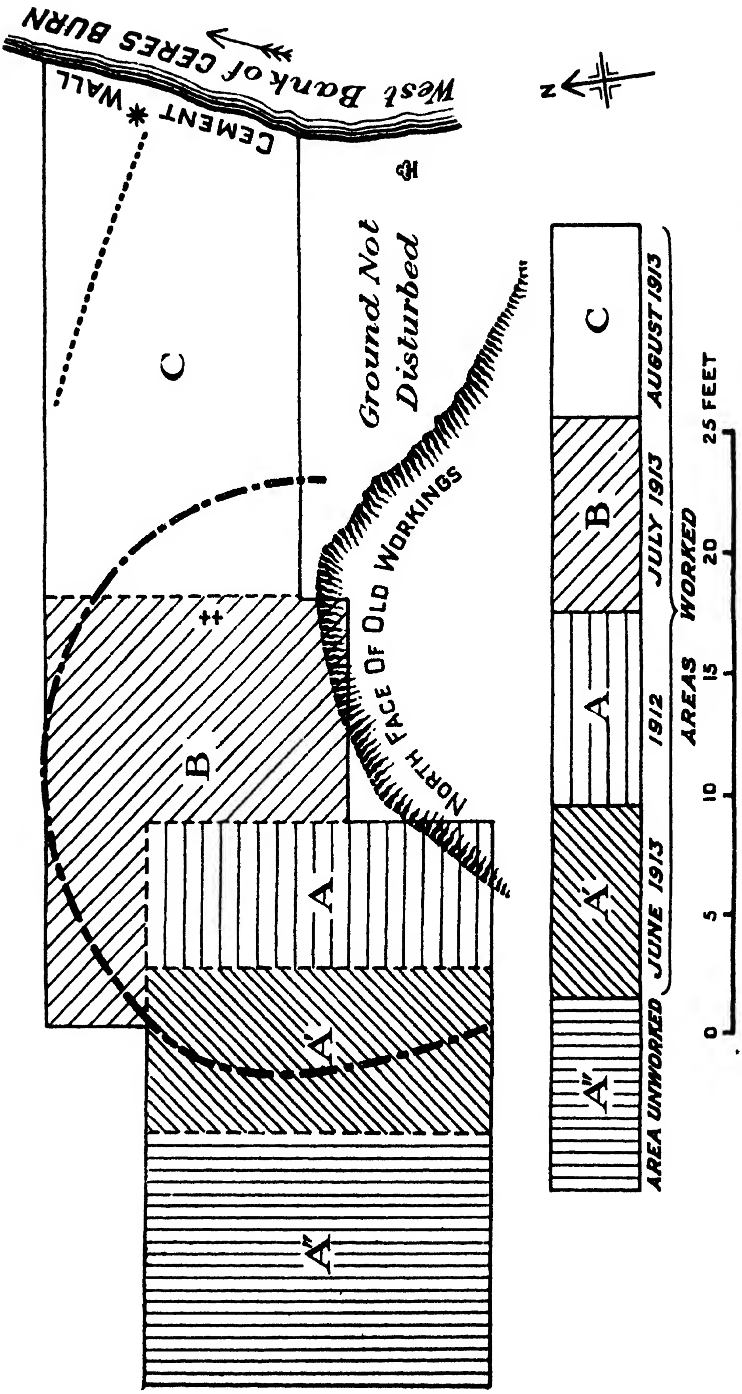
The remains occur as carbonised impressions on the fine-grained pale-yellow stone, and sometimes are to be found crowded together. Sir A. Geikie has remarked that ' the Dura Den sandstone does not so much mark a definite palæontological subdivision as an exceptional area where the organisms were rapidly killed and buried in great numbers.'[1]

On the other hand, Dr. Traquair correlated the Dura Den fish fauna with that of the highest subdivision of the Upper Old Red Sandstone on the south side of the Moray Firth. Dr. Traquair's list of fishes found at Dura Den during the earlier excavations is given below:[2]

Bothriolepis hydrophila, Ag.
Phyllolepis concentrica, Ag.
Glyptopomus minor, Ag.
Glyptopomus kinnairdi, Huxl.
Gyroptychius heddlei, Traq.
Holoptychius flemingi, Ag.
Phaneropleuron andersoni, Huxl.

In the spring of 1912 the Dundee local Committee of the British Association began excavations with the view of re-exposing the fish-bed at Dura Den. The work was carried on under the supervision of Mr. A. W. R. Don. The exact site of the previous diggings was unknown, but, according to local tradition, many of the first specimens had been obtained from the sandstone forming the bed of the stream and from an excavation on the left side between the stream and the mill-lade. After some trial explorations the fish-bed was eventually struck, and part of the old workings was exposed. The latter lay 30 feet to the west of the stream, just opposite the north end of the garden belonging to the house known as ' The Laurels,' now in the occupation of Dr. Graham Campbell. A pit was opened from the base of the old workings in the direction of the mill-lade, and the fish-bed was found to lie at a depth of nine feet from the surface. Only a small

[1] 'The Geology of Eastern Fife' (*Mem. Geol. Surv.*), 1902, p 59.
[2] 'The Geology of Eastern Fife' (*Mem. Geol. Surv.*), 1902, p. 58.



— — — Outer limit of rich fish-bearing zone. -------------- Sandstone layer with fragmentary fish remains.

• Locality of specimen containing *Phyllolepis* and *Bothriolepis*. ‡ Locality of specimen containing *Bothriolepis*.

Fig. 3.—Ground-plan showing areas excavated in 1912 and 1913, and north face of Old Workings at Dura Den.

part of the fish-bed was then worked. A few good specimens were obtained, and were on view when the locality was visited during one of the excursions arranged in connection with the Geological Section of the British Association Meeting at Dundee in 1912.

Work was resumed by our Committee on May 5, 1913, and proceeded more or less continuously to the end of August 1913. The pit, opened in 1912, having been partly refilled, had to be cleared again. As stated in the preliminary report issued last year, a definite plan was followed in the excavations. The fish-bearing zone was uncovered and removed in successive sections (fig. 3).

The sandstone layer, rich in fish-remains, is restricted to a zone about two inches thick. It lies at an average depth of nine feet from the surface, and is overlain by about four feet of comparatively barren sandstone, capped by about four feet of loose superficial materials. It was decided to work the fish-bed in the direction in which the fish-remains appeared to be most abundant. As the operations extended towards the mill-lade in the area marked A′ in fig. 3, the sandstone did not yield fishes, as if the limit of the rich fish-bearing zone had been reached in that direction. The arrangement was then made to carry on the excavations towards the stream and just north of the face of the old workings.

The finest specimens of fossil fishes and the largest number were obtained in the middle section (area marked B in fig. 3) and in the immediately adjoining parts of the other two sections (A and C in fig. 3). The greater part of the area marked C in fig. 3 proved to be somewhat disappointing, though one slab containing twenty specimens was found there and a fine example of *Phyllolepis* quite close to the stream. Good specimens, however, were scarce in section C outside the limit of the rich fish-bearing zone. In the north-east corner of it near the stream a sandstone layer with fragmentary fish-remains was traced for a short distance.

It is worthy of note that large scales of *Holoptychius* were obtained in the sandstone three feet above the fish-bed, and that fish-scales in a fragmentary condition were found scattered throughout the sandstones above that zone. No fish-scales were detected below that horizon, although the excavations were continued downwards for nearly two feet beneath that zone.

Fine examples of sun-cracks were seen in the sandstone at depths varying from two to four inches below the fish-bed, and, at one locality, one inch above that horizon. This feature is suggestive, and probably points to desiccation as a cause of the death of the fishes in a shoal at this locality.

In all forty-two slabs of stone with well-preserved fish-remains were obtained. These were photographed by Mr. Dunlop, and the photographs were sent to Dr. Smith Woodward for determination. About fifty fragmentary specimens were collected which were not photographed. The whole collection has been stored in an adjoining mill under lock and key.

The expenses connected with these detailed investigations have exceeded the British Association grant of 75*l*. and the contribution of

12*l*. from Mr. Bolton of the Bristol Museum. The Curator of Ichthyology in the American Museum of Natural History, New York, has offered a donation towards the expenses on condition that some of the specimens be given to that Museum. The Committee have accepted this offer.

On June 19 the Chairman, the Secretary, Dr. Smith Woodward, and Mr. Dunlop visited Dura Den. Each specimen was then examined by Dr. Smith Woodward, and a scheme of distributing the fish-remains to various public institutions was adopted by the members of the Committee who were then present. The distribution will be carried out during this summer.

The report of Dr. Smith Woodward is appended:

Preliminary Report on the Fossil Fishes from Dura Den.
By Dr A. SMITH WOODWARD.

The very large majority of the fishes found during the excavations at Dura Den are examples of *Holoptychius flemingi* and most of the slabs exhibit no other species. Specimens of *Glyptopomus kinnairdi*, *Glyptopomus minor*, *Phaneropleuron andersoni*, and *Bothriolepis hydrophila* occur but rarely. All are nearly complete, as usual, having been suddenly buried; and it is probable that when studied in detail the new collection will make some small additions to our knowledge of the species represented.

The only important novelty is a nearly complete specimen of *Phyllolepis*, which shows for the first time the arrangement of the dermal plates in this rare fish, and apparently determines its affinities. The genus has already been recorded from Dura Den,[3] but it is known only by detached plates. The armoured portion of the fish is oval in shape and depressed, so that the fossil is exposed from above or below. The surface shown is covered chiefly with two large plates, one behind the other, each irregularly hexagonal in shape and slightly broader than long. The anterior plate is somewhat the smaller and narrower, and the regularity of its concentric ridge-ornament is interrupted by waviness in lines apparently of slime-canals which radiate symmetrically from the centre to the periphery. The posterior plate is ornamented exactly like the imperfect typical plate of *Phyllolepis concentrica* from Clashbennie.[4] Round the anterior plate are arranged four pairs of small plates, which decrease in width forwards. Their ridge-ornament is peculiar in being concentric only with two or three of the margins of each plate and running out at right-angles to the inner margin. The postero-lateral plate is long and narrow and much the largest, extending along the posterior two-thirds of the anterior median plate. The next plate forwards, also long and narrow, is much less than half as large as the postero-lateral just described, and the two pairs of anterior plates are comparatively small. This series of plates on each side is continued behind by another still larger plate, which flanks somewhat less than the anterior half of the posterior median plate and ends postero-laterally in a produced angle or cornu.

[3] A. S. Woodward, *Catal. Foss. Fishes Brit. Mus.*, Pt. II. (1891), p. 314.
[4] L. Agassiz, *Poiss. Foss. Vieux Grès Rouge* (1844), p. 67, pl. xxiv. fig. 1.

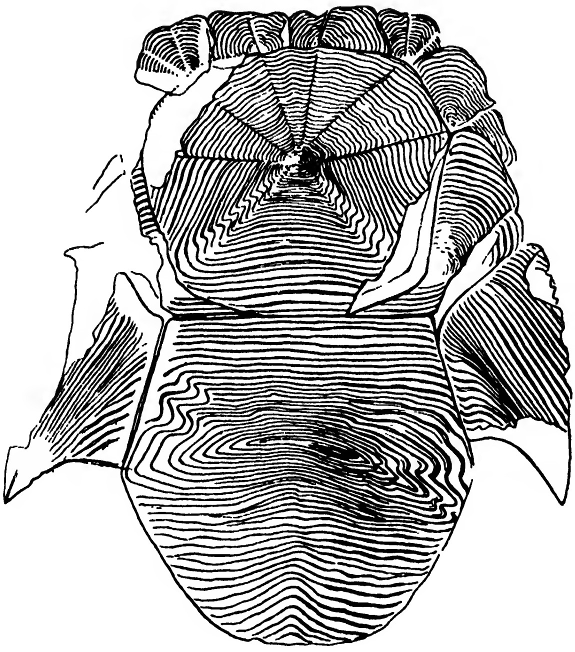


FIG. 4.—*Phyllolepis concentrica*, Ag.; ventral or dorsal aspect of dermal armour, showing arrangement of plates, two-thirds natural size.

Illustrating the Report on the Upper Old Red Sandstone of Dura Den.

[*To face page* 122.

The ornamental ridges here radiate chiefly from the posterior cornu and the outer margin and are most widely spaced on the postero-internal part of the plate. No vacuities are observable in any of the plates, but all of the anterior pairs are crossed by slime-canals in continuation of the radiating canals on the anterior median plate. The total length of the fossil is 12.5 cm.

The ornamentation of the posterior median plate of the specimen just described seems to justify its reference to the typical species, *Phyllolepis concentrica*, already known by imperfect plates from Clashbennie, Perthshire. It is also interesting to add that some of the other plates agree well with specimens found in association with *P. concentrica* in the Upper Devonian of Belgium.[5] The ornament of the anterior median plate corresponds with that of the so-called *P. corneti*,[6] while both the ornament and shape of some of the lateral plates are essentially the same as those of the small plates named *Pentagonolepis*.[7] The plates forming the lateral cornua do not appear to have been previously seen.

The whole fossil is most suggestive of the ventral aspect of the curious Devonian Ostracoderms *Drepanaspis*[8] and *Psammosteus*.[9] It agrees with *Drepanaspis* in showing two principal median plates one behind the other, though in *Phyllolepis* they are more nearly equal in size. It corresponds with *Psammosteus* in exhibiting a prominent pair of lateral cornua at the hinder end of the series of small marginal plates, opposite the middle of the posterior median plate. It differs from both in lacking separate small tessellated plates. There is, therefore, not much doubt that *Phyllolepis* is a genus of Ostracoderms most nearly allied to the Drepanaspidæ or Psammosteidæ.

Antarctic Whaling Industry.—Report of the Committee, consisting of Dr. S. F. Harmer (*Chairman*), Dr. W. T. Calman (*Secretary*), Dr. F. A. Bather, Dr. W. S. Bruce, *and* Dr. P. Chalmers Mitchell, *appointed to provide assistance for Major G. E. H. Barrett-Hamilton's Expedition to South Georgia to investigate the position of the Antarctic Whaling Industry.*

By kind permission of the Trustees of the British Museum the Committee arranged for Mr. P. Stammwitz, a taxidermist employed at the Natural History Museum, South Kensington, to accompany Major Barrett-Hamilton to South Georgia; and the greater part of the grant

[5] M. Lohest, 'Recherches sur les Poissons des Terrains Paléozoïques de Belgique,' *Ann. Soc. Géol. Belg.*, vol. xv. (1888), *Mém.*, pp. 155-167, pls. x., xi.
[6] M. Lohest, *loc. cit.*, p. 157, pl. x. fig. 6.
[7] M. Lohest, *loc. cit.*, p. 161, pl. xi. figs. 1-8.
[8] R. H. Traquair, 'Additional Note on *Drepanaspis Gemündenensis*, Schlüter,' *Geol. Mag.* [4] vol. ix. (1902), pp. 289-291.
[9] A. S. Woodward, 'On the Upper Devonian Ostracoderm, *Psammosteus taylori*,' *Ann. Mag. Nat. Hist.* [8] vol. viii. (1911), pp. 649-652, pl. ix.

placed at the disposal of the Committee has been expended in paying his salary and in making certain preliminary payments. He sailed with Major Barrett-Hamilton on October 6, 1913, and work was commenced at South Georgia immediately after their arrival on November 10.

Early in the new year news was received that Major Barrett-Hamilton had died suddenly at South Georgia on January 17, while his inquiries were in full progress. This unlooked-for event, which the Committee record with profound sorrow, naturally altered the entire prospects of the expedition. Mr. Stammwitz had no alternative but to return at once, and after making arrangements for the despatch of the specimens which had been collected, he took the first opportunity of leaving South Georgia, bringing with him the notebooks containing Major Barrett-Hamilton's observations. At the request of the Colonial Office, and with the approval of the Trustees of the British Museum, these notebooks have been placed in the hands of Mr. Martin A. C. Hinton for examination. It is hoped that the results of the work which Major Barrett-Hamilton had done before his death will thus not be entirely lost. The collections brought home comprise a very valuable series of specimens—in particular, flippers, complete sets of baleen, and other anatomical material from the blue whale, the common rorqual, and the humpback whale. These specimens have been presented to the Natural History Museum by Messrs. Chr. Salvesen & Co., at whose whaling station they were obtained, and they should be of service in helping to decide the much-debated question whether these Antarctic whales are specifically identical with their northern representatives.

A few birds were obtained at South Trinidad on the outward journey, and a certain amount of dredging and shore-collecting was done at South Georgia. The collection made includes marine invertebrates and fishes, bird-skins, plants, and a few insects and rock-specimens. These have been handed over to the Natural History Museum, where arrangements are being made to have them determined, and if necessary reported on, by specialists.

At the request of the Meteorological Office, Mr. Stammwitz took a series of observations on sea-temperatures and ice-drift while at South Georgia, and these are now being utilised by the Office.

The Committee wish to record their appreciation of the value of the assistance which was given to the expedition by Mr. J. Innes Wilson, Stipendiary Magistrate of South Georgia, Messrs. Chr. Salvesen & Co., and Mr. Henriksen, the manager of their Leith Harbour Whaling Station, Messrs. Bryde & Dahl, the Tönsberg Whaling Company, and other individuals and whaling companies connected with South Georgia.

The amount actually expended is less by 15*l.* than the total (90*l.*) allotted to the Committee, and it is not proposed to apply for this balance.

Belmullet Whaling Station.—Report of the Committee, consisting of Dr. A. E. SHIPLEY *(Chairman)*, Professor J. STANLEY GARDINER *(Secretary)*, Professor W. A. HERDMAN, Rev. W. SPOTSWOOD GREEN, Mr. E. S. GOODRICH, Professor H. W. MARETT TIMS, *and* Mr. R. M. BARRINGTON, *appointed to investigate the Biological Problems incidental to the Belmullet Whaling Station.*

THE Committee acting through Professor Herdman arranged with Mr. J. Erik Hamilton and Mr. R. J. Daniel, two post-graduate research students of the University of Liverpool, for the prosecution of their researches in 1913. They proceeded to Belmullet on June 25 and Mr. Hamilton remained until the end of the fishery. Mr. Daniel retired from the investigations on August 26, having been appointed to a post under the Board of Agriculture and Fisheries. Mr. Hamilton's Report is appended.

The Committee desire to express their thanks to Mr. R. M. Barrington for considerable financial assistance. They have been enabled owing to his generosity to arrange with Mr. Hamilton for the further prosecution of the work in 1914. They have now experience with three investigators—Mr. Lillie, Mr. Burfield, and Mr. Hamilton—and they find that the annual expense is about 45*l*. They attach great importance, both from the scientific and economic sides, to the further continuation of these investigations, and beg to apply for reappointment with a grant of 45*l*. for the summer of 1915.

Report to the Committee by J. ERIK HAMILTON, *B.Sc.*

I.—*Introduction.*

In June 1913 Mr. R. J. Daniel and I proceeded to the Blacksod Bay Whaling Station on Ardelly Point, Blacksod Bay, Co. Mayo, Ireland, to continue the work carried on by Mr. S. T. Burfield, B.A., in 1911.[1]

The flensing plane was clearly visible by telescope from the hotel, and the whaling steamers are compelled to pass the Point whenever they come in. In consequence no whale escaped notice, as might otherwise have happened on account of the distance from the Station.

Our first whale was examined on the morning after our arrival, *i.e.*, on June 26, the last on September 2. As Mr. Daniel was appointed to a post under the Board of Agriculture and Fisheries, he had to leave Blacksod on August 26 for his new duties. Consequently the working up of the collections and the preparation of this Report have been left in my hands.

I desire to express my heartiest thanks to Professor W. A. Herdman,

[1] *British Association Report*, 1912, p. 145.

F.R.S., who has given advice and help of great value during the time which was spent in his Laboratory in working up the materials obtained.

To Captain Lorens Bruun and Mr. D. Bingham sincere thanks are due from Mr. Daniel and myself for the way in which they assisted us at the Station. We would also wish to mention that on many occasions the men employed at the Station helped us in the most obliging manner.

Two steamers continue to be used, both fitted with wireless telegraphy, which is employed solely for communication between the boats. As a result of the possession of this apparatus, if one boat finds whales in numbers too great to be dealt with unaided, the other steamer may be called up to assist in making the most of a fortunate find.

Burfield[2] has stated the disadvantages of work at a commercial factory, and I wish to lay particular emphasis on the rarity with which really fresh whales are brought in. It is exceptional for a whale to be anything other than decomposing. Even in those sufficiently fresh to be fit for food the carcase is quite hot in the deeper parts owing to *decomposition*, *while in the other cases carcases lying on the flensing plane fizzle and splutter* wherever a cut in the blubber permits the internal gases to blow off.

Sperm Whales are particularly obnoxious, as they are brought from considerable distances. They are frequently caught at Rockall, 240 miles away, and they smell strongly of cuttlefish. In two Sperm Whales which we saw part of the intestine was blown out through the back of the animal by pressure of gases produced by decomposition, and from one specimen a great spout of blood and oil was projected with considerable force over one of the investigators.

About thirty-eight Irishmen and fifteen Norwegians are employed when work is in full swing. Of the Irishmen one is timekeeper and another is second flenser, but all the other skilled workmen are Norwegians.

The 1913 season was the best which the Blacksod Bay Whaling Company has had up to the present. Sixty-four whales were brought in. The whalemen state from their experience that in fine, calm weather the whales go far out for food, and it is the case that during the splendid weather of August very few were taken. But the largest number of whales for a given number of days was brought in between August 27 and September 9, when the weather was still fairly fine. Nearly three thousand barrels of oil were shipped to Glasgow, to which port all the produce of this Station is sent. There were also manufactured about fifteen hundred bags of guano.

All whale oils at present average 20*l.* per ton ($=5\frac{1}{2}$ barrels), sperm oil and spermaceti having fallen considerably since 1911. The oil is used for the manufacture of explosives, soap, &c., with the exception of the two sperm products. The oil of the Sperm Whale is used for lubrication only, while spermaceti is largely utilised in the manufacture of church candles.

Whalebone from *Balænoptera musculus* and *B. sibbaldii* is now 65*l.* per ton. The baleen of *Megaptera* is of very inferior quality,

[2] *Op. cit.*, p. 146.

while *B. borealis* yields whalebone of considerably greater value, although, since this is a small species, the plates are not of great length.

The flesh of *B. sibbaldii* has an excellent flavour even when taken from a large specimen. As it is full of oil it must be soaked in salt water and vinegar for several hours before being used. If this precaution is observed, it is almost impossible to distinguish whale-meat from good quality of beef-steak. The flesh for food is generally cut from the lateral post-anal region. On the Japanese Stations the entire carcases of the whales taken are, or used to be, sold on the market for food, it being more profitable to dispose of the animals in this manner than to boil them down for oil and guano. In Norway also a considerable amount of whale-meat is utilised by butchers. It is usually salted as soon as the whales are flensed, and is seldom placed on the market in the fresh condition. On account of the extreme rapidity with which whales decompose very few of the Blacksod Company's whales could be used as food.

The attempts to recover the glue from the water resulting from the various cooking processes applied to blubber, meat, &c., have failed. The reason for the failure lies in the amount of steam which is required to evaporate down the solution. This steam consumption necessitates the use of so much coal that the expenditure is not covered by the price received for the glue which results from the process of evaporation.

In whale-hunting the shot which is generally attempted is aimed at a point behind the pectoral fin, as the animal here presents a large target, and the cast-iron harpoon head, with its charge of blasting-powder, is most likely to prove fatal when exploded in the thoracic cavity. The shot, as a matter of fact, which explodes beside the vertebral column in an anterior position is the most fatal. When this happens the whale dies instantaneously. On the other hand, the harpoon may fail to explode. In this case nothing can be done at the moment except to let the harpoon line run out. The whale may rush along the surface or descend almost vertically. If a surface run is made the engines are put at full speed ahead in order to avoid straining the harpoon rope, which is three-inch manilla cable. When the whale dives down there is serious risk of the rope snapping. One such case occurred to our knowledge during the 1913 season. Only a few fathoms of cable were lost on this occasion, but at other times whales have been known to take out the whole of the three or four hundred fathoms attached to the harpoon, and then to break the line at the bow of the boat. The whale is very much exhausted after a deep dive such as this, and when it returns to the surface another harpoon is fired into it, which almost invariably proves fatal. Even if the rope is broken the animal is usually so fatigued that it is readily approached and secured. We were informed by a very experienced Norwegian whaler that it has happened that a steamer, having become fast to a wounded whale, has 'played' it for as much as thirty hours before the *coup de grâce* could be delivered.

II.—*Numbers and Species taken at the Blacksod Bay Station in* 1913.

The number of whales taken in the 1913 season was sixty-four, as has been stated. Of these fifteen were brought in previous to our arrival; we therefore examined forty-nine. Five species came under our notice, in the following numbers:—

Finners (*Balænoptera musculus*, L.)	37
Blue Whales (*B. sibbaldii*, Gray)	4
Sejhval (*B. borealis*, Lesson)	1
Humpback (*Megaptera longimana*, Rud.)	1
Sperm Whales (*Physeter macrocephalus*, L.)	6

Of the fifteen taken before June 26, eleven were Finners and four Sperm Whales.

III.—*Measurements and Proportions.*

(See Tables at the end of this Report.)

In continuing the series of measurements adopted by Burfield, who followed True,[3] we found that in some cases it was not easy to determine the points from which measurements were taken, within six inches or a foot. We therefore fixed on a series of standards which enabled us to make measurements from corresponding points on every whale. These points I attempt to define as follows:—

(1) *Total length.* Taken between a position opposite the end of the upper jaw to a point opposite the notch between the flukes, in a straight line. When, as in the case of our first two whales, and in the cases of those taken before our arrival, we obtained the Norwegian measurements, two points had to be observed: (*a*) that Norwegian feet are equal to 12½ English inches; (*b*) that the Norwegians measured to the tip of the lower jaw, which projects beyond the rostrum, and therefore an allowance must be made for this in reducing to 'total length' according to our standard. Eighteen inches was the allowance made, and this was probably erring on the side of taking off too little rather than too much.

(2) *Tip of snout to anterior end of the groove between the spiracles.* This line is quite sharply marked.

(3) *Tip of snout to posterior insertion of pectoral fin.* This measurement and the next were taken on the dorsal side of the animal.

(4) *Tip of snout to posterior insertion of dorsal fin.* This fin slopes away behind as well as in front. The 'posterior insertion' was therefore found in the following manner—a line being dropped from the apex of the dorsal fin, at right angles to the body, the point where it cut the outline of the body was taken as the posterior insertion of the dorsal fin. Apart from this method I do not think that any point of equal value in every specimen could have been found.

(5) *Tip of snout to centre of eye.*

(6) *Centre of eye to anterior end of auditory slit.*

(7) *Notch of flukes to posterior end of anus.*

(8) *Notch of flukes to anterior margin of umbilicus*, which was the most definite border of that area.

[3] *Smithsonian Contributions to Knowledge*, vol. xxx.

Measurements of the Pectoral Fin.

(9) *Length of anterior border.* There is an eminence at the anterior, proximal end of the pectoral fin. Immediately anterior to this is a slight depression. The eminence marks approximately the position of the head of the humerus. Our measurement was taken from the tip of the flipper, along the anterior margin, to the centre of the eminence.

(10) *The posterior length* was taken from the tip, along the margin, to the axilla. This measurement was not easy to take, as the flipper was almost always directed backwards and the axilla compressed. When this was the case the exact point of proximal measurement had to be found by judgment, as the size of the limb and the rigidity of the muscles attached to it entirely prevented any attempt at altering the attitude of the fin.

(11) *The median length* was taken from the tip in a straight line, down the centre of the flipper, to a point on a line drawn through the axilla in such a manner as to carry on the outline of the body. In taking this measurement the idea was to estimate the extent to which the limb projects from the body.

(12) *The greatest breadth of the pectoral fin* was generally found to be about half-way between the tip and the insertion.

(13) *The length of the dorsal fin* was taken from the posterior insertion as defined above, and the anterior insertion, which could usually be found with moderate accuracy. This measurement cannot be regarded as more than approximate.

The flukes had been cut off every whale before it was towed in, but on *B. musculus* (No. 19) the right fluke had not been completely severed. Measurement gave 7 ft. 5 in. as the distance between tip of fluke and caudal notch. The spread of the flukes was therefore 11 ft. 10 in.

Total Length.

The following table shows the averages of total length of the five species taken, and a more detailed analysis of the total measurements of the Finners at different stages. I have taken as the minima for adult males and females the dimensions adopted by Burfield,[4] who followed True:—

Finners (*B. musculus*, L.)

		Ft.	in.
Average length of all finners	(37)	59	9
,, ,, ,, females	(17)	60	7
,, ,, ,, males	(20)	59	0
,, ,, ,, adult females	(12)	64	0
Maximum for females		69	8
Minimum for females		48	7
Average for adult males (16)		60	8
Maximum for males		66	0
Minimum for males		46	7

[4] *Op. cit.*, p. 160.

It may be useful to compare these results with those of Burfield, who gives similar statistics for the year 1911:—

	1911.		1913.		
	Ft.	in.		Ft.	in.
Average for all specimens (53)	63	0	(37)	59	9
„ „ females (21)	64	3	(17)	60	7
„ „ males (25)	62	5	(20)	59	0
„ „ mature females (20)	64	8	(12)	64	0
„ „ „ males (23)	63	2	(16)	60	8
Maximum females	75	0		69	8
„ males	68	9		66	0
Minimum females	54	3		48	7
„ males	53	3		46	7

As all the figures for 1913 are perceptibly smaller than the corresponding figures of Burfield for 1911, it suggests the probability that the larger whales are being killed off, although it would be useful to have the figures for other years in order to verify the diminution in size which appears to be taking place.

Blue Whales (*B. sibbaldii*, Gray).

All the Blue Whales taken in the 1913 season were brought in during our stay:—

	Ft.	in.
July 10, female	78	2
Aug. 18, „	70	7
„ 20, „	68	6
Sept. 9, „	68	0

Comparing these also with Burfield's figures[5] for the same species we have:—

	1911.		1913.		
	Ft.	in.		Ft.	in.
Average for all females (4)	75	4	(4)	71	3½
Maximum for females	84	0		78	2
Minimum for females	64	6		68	0

True gives 72 ft. as the minimum for mature females, but our second specimen (70 ft. 7 in.) had a fœtus 8 ft. long, and was therefore an adult animal. (True's figure was based upon two specimens only.)

Sperm Whales (*Physeter macrocephalus*, L.).

Ten Sperm Whales were taken in 1913; of these six were taken after our arrival, and all the specimens were males.

	Ft.	in.
Average of all Sperm Whales (10), males	58	3
Maximum, Sperm Whales	62	6
Minimum „ „	53	0

Sejhval (*Balænoptera borealis*, Lesson).

One specimen only taken in 1913, female . . . . . 46 ft. 7 in.

Humpback (*Megaptera longimana*, Rud.).

Only specimen taken, male . . . . 45 ft. 8 in.

[5] *Op. cit.*, Table IV., p. 161.

IV.—*General Observations on the Various Species.*

1. Finners (*B. musculus*, Gray).

(*a*) *Colouration.*—None of the specimens of the Finner examined by us presented any remarkable colour variations. On very many animals white marks occurred in the pigmented areas, as noted by Burfield.[6] Some of these seemed to be the scars left after *Penella* has dropped off. In many cases we found the sores which had been produced by the parasite, although the latter was not present. These sores presented the same appearance as the wounds in which the parasites were still fixed.

Notes on individual specimens:—

No. 10.—There were a few white patches on the tongue, which may have been the result of lesions, or due to mere absence of pigment.

No. 11.—A pale, grey line, about three-eighths of an inch broad, but gradually widening, ran from the ear aperture upwards and backwards to a point level with the anterior margin of the pectoral fin, and about 9 in. above the level of the ear-hole. From here onwards it broadened out and swept round in a semicircle to the anterior margin of the pectoral. On the top of the head there was a triangular grey patch, having as apices the angle of the jaw, the nape at the level of the pectoral, and a point about half-way down the margin of the rostrum.

No. 19.—The fœtus of No. 19, 15 ft. in length, displayed the same areas of colouration on the head as an adult. The dark colour of the body was defined in front by the same line sweeping back from the eye, through the ear, and down to the pectoral, while dorsally it was limited by another line curving backwards, and dorsally, from the eye.

No 24.—The black colour extended in flecks from the left as far as the mid-ventral line, in the region of the ventral furrows.

No. 29.—The belly had a yellow tinge, but, as the animal was very decomposed, this was probably not the case during life, as, when they have been dead for some time, whales become very discoloured. There were streaks of black on the left side of the belly.

There is always a certain amount of pigment in the more lateral and posterior furrows. In Nos. 41 and 42 this was specially well developed, extending almost to the mid-ventral line from the left side. The furrow region of No. 42 had also a number of pale purple stains in its pure white. These were due to the presence of blood in the cutaneous vessels, which appeared to be gorged. They resembled bruises, but the epidermis was undamaged. This whale displayed a few of the 'galvanised-iron' markings which are characteristic of the Blue Whale. These were in the post-anal region. It had also several incised wounds in the belly, about 8 in. long, partly healed, but still raw. No. 45 had a large island of black pigment on the posterior furrow region of the left side.

[6] *Op. cit.*, 175.

There are frequently extensive white patches on the dark area, caused by the chafing of the whale against the side of the steamer as it is being towed in. These, however, are easily distinguished from the naturally unpigmented areas.

(*b*) *Ventral Furrows.*—In the Finner the number of pectoral furrows is exceedingly variable. We found a maximum of eighty-four, and a minimum of fifty-four. In nearly half of the cases a median furrow could be distinguished, the presence of which appears to have escaped notice up to the present. The number was estimated by finding the median furrow, and counting all those between it and the pectoral fin of the side which happened to lie uppermost. As the fin is approached the furrows become less marked, and it is not easy to discern the furrow nearest the fin. The skin in the axillary region is much folded longitudinally, which further complicates matters. By doubling the number of furrows thus counted and adding the unpaired median an estimate of the total number was made. The furrows in the smallest fœtus (3 ft. 11 in.) were represented by mere lines, and could not be counted with accuracy. The folds of twenty-seven specimens were counted, of which twelve had no distinguishable median furrow. The average depth of these furrows was about ·68 in. (deduced from eight measurements), and the average horizontal distance between points above the middle lines of the same number of furrows was 1·85 in., varying from 1·37 in. to 1·96 in. These measurements were taken from a portion of blubber lying on the plane and not stretched in any way.

It is essential that the counting should always be made in the same position, as some of the folds do not run the whole length of the furrowed area. There does, however, appear to be a certain amount of uniformity in the folding, the shorter folds corresponding with each other in different whales, if not with absolute accuracy, at any rate nearly so.

(*c*) *Tongue.*—The colour of the tongue as a whole is dark grey, but the area which is the morphological upper surface, which is distinguishable from the morphological lower surface, shades off into pink towards the 'tip.'

2. Blue Whales (*B. sibbaldii*, Gray).

Colouration.—The only point to which I wish to draw attention is that there are some curious markings on the skin, especially ventrally, but not confined to that aspect. These markings take the form of curved, darker and lighter lines radiating from a common centre. The area of such markings is about 8 in. long and 4 in. wide. Where there is a number of markings crowded together, the appearance of the skin forcibly reminds one of the pattern produced on the surface of 'galvanised iron.' These markings occur in considerable abundance on large areas of the skin.

3. Sejhval (*B. borealis*, Lesson).

External Characters.—The solitary example of this species taken was a female. Although a small species (this specimen was only

46 ft. 7 in. long) it has a robust figure, and the dorsal fin is of great height as compared with that of the Finner. This specimen had been lying at the buoy from Thursday afternoon until it was hauled up on Saturday morning, and was therefore considerably decomposed. The dorsal surface was dark grey, as was also the post-anal area of the ventral surface. The pre-anal region was for the most part of white colour, asymmetrically arranged. There was a considerable amount of black blotching towards the left side of this area, and on this side the white area was continued backwards in a large patch. There was no white patch corresponding with this on the right side. The symphysis was pigmented, and here there was a whorled design similar to that on the skin of the Blue Whale as described above. The upper lips and the lower side of the anterior end of the rostrum were nearly black, and were finely tuberculated. The inner (palmar) surface of the pectoral fins was pale, streaky, greenish grey, with black streaks intermingling with the less dark flecks. The right side was a dark grey, nearly black. This may have been due to the fact that the right side had been more exposed to the sun than the left side as the animal lay at the buoy.

The ear aperture was small. The tongue presented an area which could be more readily recognised as the dorsal surface than in the case of the Finners.

4. Humpback (*Megaptera longimana*, Rud.).

External Characters.—The form of the single specimen taken was robust, reminding one somewhat of the figure of the Sperm Whale. The dorsal fin was placed far back and was much falcated, and of moderate height. The colour was slate-chocolate, but very dark, almost black. Pure white, splashed, ring-like marks occurred on the lower jaw and on the dorsal side of the pectoral fin. The outer sides of the right mandible and of the right upper jaw were white, but on the left only the inner sides were unpigmented. The ventral surface of the flukes was white. The ventral folds were few in number (23), and wide; running up the centre of each groove was a low ridge about ·375 in. high, of triangular section. The folds were about 4 in. wide and 5 in. apart. The median fold, with the next on each side, also the fold next the right pectoral fin, were mere narrow grooves.

There was a deep groove running from the angle of the jaw downwards and backwards to a point about one-third of the width of the pectoral fin from its anterior margin. Another groove ran from a point a little above and in advance of the termination of this groove to a point somewhat behind the posterior margin of the pectoral, and a little above it. Unlike the small external auditory aperture of the Balænopterids the opening in this specimen was 8 in. long. The upper surface of the snout had the characteristic knobs of the species. In the mid-dorsal line there were five, the first being 11 in. from the tip of the snout, and the last 13½ in. from the spiracle. The spaces between the knobs, running from the snout, were 10½, 18, 12½, 23¼ in. respectively. There were also two series of

lateral knobs, following the margins of the rostrum, nine on each side in a consecutive row. Inside these rows, at their posterior ends, was a second series of four knobs on each side. The knobs of the inner, short row were set beside those of the outer row, forming pairs with them. But the two sides were not symmetrical. Thus, if the knobs of the outer row are numbered 1 to 9 from before backwards, on the left side 7, 8, and 9 were paired, and there was a single knob of the inner row *behind* the termination of the outer series. On the right side 6, 7, 8, and 9 were paired, and there was no unpaired knob posteriorly. Several of the left-side knobs had a hair on the summit, which suggests that the knobs may be overgrown hair-papillæ, and their arrangement does correspond fairly closely with the arrangement of the hairs of *Balænoptera*. On the symphysis there were four knobs on the right side and five on the left. In each case there was a vertical row of three. The knobs varied in size, a large one being 2 in. high and 4 in. across the base.

The eye appears to be rather more movable than in *Balænoptera*. The pectoral fin has an exceedingly irregular posterior margin. There were seven conspicuous elevations on it, varying in length from 10 to 27 in.

5. Sperm Whale (*P. macrocephalus*, L.).

(*a*) *External Characters.*—Six specimens were examined. The general body-colour is pale greyish chocolate, rather more lead-like ventrally. Between the genital aperture and the umbilicus there is a splashed chevron-shaped mark of a pale grey colour. The apex is on the umbilicus, and directed forwards, the 'arms' being about 4 ft. apart at the tips. There are also irregular grey flecks all over the ventral surface. In some specimens the front of the head is barred horizontally with streaks which are almost white in colour. They are broadest in the middle and taper towards the ends. The whole of the head, and in particular the anterior, ventral, and lateral areas, have numerous weals and sucker marks which have been produced by the arms and suckers of the cuttlefish, which are the main food of this species. As might be expected from the fact that the suckers of many of the molluscs are armed with chitinous teeth, the sucker marks take the form of rings of minute pricks. One such mark was 3½ in. across. The fifth Sperm Whale had a large patch of pure white on the umbilicus, and an extensive array of grey streaks on the left side, in addition to the grey chevron.

(*b*) *Spiracle.*—In every case the left spiracle alone was functional. On the right side, however, after the blubber has been removed, there is a compressed cavity, approximately oval in shape, about 18 in. long and 10 in. wide, in the position corresponding with that of the obliterated right spiracle. The lining of this cavity is heavily pigmented with the same colour as the outer surface of the animal. There can be no doubt that this is the vestige of the right spiracle, although no passage was observed running backwards from it in the direction of the pharynx.

(*c*) *Mouth.*—The palate and floor of the mouth have a general pale grey colour and have a large number of small grooves, about

an inch in length, running longitudinally. On the palate of the first Sperm Whale there were two large dark blotches. That on the left was about 8 in. long, that on the right 11 in.

(*d*) *Tongue.*—The tongue of *Physeter* affords a striking contrast to that of a Mystacocete. It is an exceedingly hard, strong structure of comparatively small size, and very nearly occludes the throat as the animal lies on the plane with the jaw gaping open. The tongue stands up from the jaw to a height of about 2 ft., and, as viewed from the front, presents a smooth, round wall, like the side of a section of wide tubing. The upper surface is wrinkled, and in front is produced into a small projection, which appears to correspond with the tip of the normal mammalian tongue. From its structure the tongue would appear to be of use in preventing the ingress of water during respiration, but in the dead animal, at any rate, this very fact of its nearly closing the throat gives the impression that the organ would be a hindrance to the swallowing of large prey. That this cannot be the case, however, is apparent from the size of the cuttlefish which we found in the stomach of one specimen, as described in Section V.

(*e*) *Teeth.*—Teeth occur in both jaws. Only those of the lower jaw can, however, be of much practical value in the capture of food, as the upper-jaw teeth are of small size, and often nearly covered with soft tissue. The lower-jaw teeth are about twenty in number on each side, and are arranged in pairs, but the two teeth of each pair are not exactly opposite to one another.

Actual numbers of teeth in the different Sperm Whales examined:—

Number 15	left side	21	right side	23
„ 16	„	19	„	19
„ 21	„	20 plus 2	„	21 plus 1
„ 22	„	—	„	—
„ 25	„	24	„	23
„ 26	„	20	„	21

The two most anterior teeth of each side project somewhat forward, but the majority of the teeth are nearly vertical, being somewhat recurved in most cases and having a slight inclination outward. The acuteness of the point is very variable, but this may be merely due to differences in age of the animals. One tooth was seen which had been broken off, but the stump did not appear to be at all decayed. In the palate there is a hollow corresponding with each tooth of the lower jaw, into which the latter fits when the mouth is shut.

The upper-jaw teeth are small, inclining backwards, and deeply embedded in soft tissue, but they do have some little use, as is demonstrated by the fact that in many cases they are much worn down by contact with the lower-jaw teeth. The most posterior of the latter are also very small, and of little use, occurring very far back. There were no teeth in the upper jaw of Nos. 16 and 26.

	Teeth in upper jaw—			
Number 15	left side	5	right side	7
„ 16	„	0	„	0
„ 21	„	8	„	7
„ 22	„	—	„	—
„ 25	„	7	„	7
„ 26	„	0	„	0

(*f*) *Dorsal Fin.*—The dorsal fin of the Sperm Whale consists of a prominent elevation, which rises to a height of from 14 to 18 in. above the line of the back. The fin is succeeded by a series of about six much smaller prominences which decrease in size towards the tail. None of these at all approaches the altitude of the dorsal fin. They are, nevertheless, quite obvious. On the ventral surface the keel of the caudal region is continued forwards towards the anus as a much more definite ridge than in the Balænopterids.

(*g*) *Flipper.*—The shape of the flipper is somewhat variable. In No. 21 the left pectoral appeared to have been damaged at some period, as there was a large notch on the preaxial side of the tip.

(*h*) *Spermaceti.*—In every specimen the quantity of this substance was large, usually constituting about one-third of the total oil yield of a whale of this species. It occurs all over the body as well as in the head, but no attention is paid to it except in the head, the rest merely contributing to the general production of 'sperm oil.' In the head there are three extensive cavities, an anterior single cavity and two lateral cavities. They all occur in the interior of a huge mass of exceedingly dense, fibrous connective tissue, which, when drained of spermaceti, is of a snowy whiteness. This mass constitutes the great bulk of the head, and rests upon the large cup-like structure formed by the bones of the rostrum. The cavities do not appear to possess definite linings, and when the oil runs out, masses of light, spongy tissue filled with the liquid fat run out also, as if they had been loosely attached to the walls of the cavity. They are probably liberated by the instruments introduced through the wall of the cavity in the process of tapping the spermaceti.

The following is the method of tapping. After the whale is flensed, the body is cut off from the head, which is left lying on its side. The whole head is covered by a thick coat of mixed muscle and tendon running longitudinally. The tendons are conspicuous, and may be removed in considerable lengths with little difficulty. The cutting of the hole in this capsule is an arduous work, and may occupy nearly an hour. A mid-dorsal and an anterior aperture are made, and when the cavities have been penetrated, the spermaceti runs out as if from a pipe. A movable wooden gutter is placed beneath the hole, by means of which the oil is run into the two open boilers, in which it is cooked.

Spermaceti is an almost colourless, transparent liquid, having a pale yellow tinge. It has not any noticeable odour, and the flavour is very faintly fishy, resembling that of a fresh duck egg. After boiling, the oil has a dark yellow colour while liquid. When cold, both before and after boiling, it sets stiff, but is not hard, the consistency being about that of lard. The uses of this oil have been indicated in the Introduction.

From the position of the spermaceti, and also of the blow-hole in *Physeter*, the following function of the former may be suggested: The food of the Sperm Whale is, in the main, composed of cuttlefish such as *Architeuthis*. As these forms are bathypelagic, it follows that the whales must descend to considerable depths to feed, and

remain submerged while feeding.[7] A very rapid ascent would be exceedingly advantageous after a prolonged immersion, and the more rapid the ascent which could be made the longer the immersion could be continued. In order to be able to ascend as speedily as possible, it would be of the greatest advantage to possess a large mass of some material, having a lower specific gravity than that of water, which would act as a float, and such a material spermaceti is. Moreover, as the mass of the spermaceti is placed in the head, and as it is of enormous size, even compared with the great mass of a Sperm Whale, the animal will always ascend head first, and probably nearly vertically, with the result that the first portion of the body to come above the surface will be the upper edge of the snout, the precise situation of the spiracle. It would appear, if this suggestion be correct, that in order to descend and to maintain a submerged condition, muscular exertion is necessary, whereas ascent is automatic, and is merely accelerated by swimming movements. These two points are in keeping with the habits of the whale as indicated above. It is possible that the astounding feat which has been credited to *Physeter*, that of hurling itself bodily out of the water, is really the result of a hurried ascent from a considerable depth, which has been so rapid that the animal has shot out of the water on reaching the surface.

V. *Food of Different Species of Whale.*

The stomachs of all the species of Mystacocetes examined contained the remains of *Meganyctiphanes norvegica* (M. Sars), sometimes in immense quantities. Nothing else was ever seen, except some fragments of flesh on one occasion, but there can be little doubt that these had been driven into the stomach by the explosion of the harpoon. No fish of any sort were seen in the stomachs of any of these whales.[8]

The stomachs of the Sperm Whales invariably contained large quantities of cuttlefish beaks, which might be readily divided into large and small sizes, but, apart from size, there was nothing to differentiate the two series of beaks (fig. 1). A practically complete specimen of one of the molluscs was found in the stomach of No. 22 (the fourth Sperm Whale). The following measurements were taken on this animal:—

	Ft.	in.
Length of the mantle	6	0
Circumference of mantle	4	0
Length of the eight short arms	6	0
„ „ tentacles	21	0
Length of tail	1	7
Width of caudal fin	1	9½
Diameter of largest sucker	0	1

In addition to this specimen, we saw fragments of others of approximately the same size. The following specimens were preserved: tip of tentacle, beak and radula in liquid, and a quantity of beaks and part of an internal shell in the dry state. An examination

[7] *Vide* Burfield, *op. cit.*, p 155

[8] *Vide* Burfield, *op. cit.*, p. 178.

of these remains leaves little doubt that the species is *Architeuthis harveyi*, Verrill[9]—the caudal fin was too much digested to indicate whether it had been sagittate or not. The distal series of small, smooth suckers are not now on the tentacle tip, but these again may have been

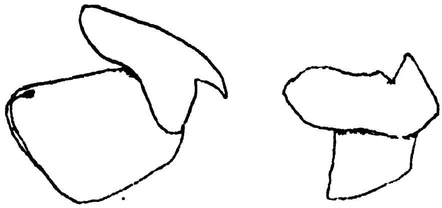


FIG. 1.—*Architeuthis harveyi*. Beak. Circ. ½.

lost owing to the same cause. No soft parts of any of the smaller cuttlefish were found.

The molluscs appear to be quite lively when swallowed, as there are scars on the heads of the whales right up to the angle of the mouth. These have been produced by the vain efforts of the molluscs to save themselves. Sucker-marks were seen on the inside of one of the whales' stomachs. Two or three jawbones of some species of predaceous fish were found in the stomach of one Sperm Whale, but, except for these, nothing but cuttlefish remains were ever noticed.

VI.—*Notes on a Few Miscellaneous Specimens Preserved.*

(*a*) One of the Norwegians gave us an object, taken from whale No. 5 (Finner), which was stated to have been 'inside the ribs.' This appears to be a pathological structure. It is a flattened, oblong object about 2¼ in. long, and 2 in. wide, and about ¾ in. thick. At one point there seems to have been a peduncle. The entire specimen has a very hard capsule of fibrous connective tissue, and is filled with a more or less reticulate mass, containing what may have been a coagulable fluid. There is a certain amount of calcification in the outer layers just beneath the capsule, and a little fat is visible on treatment with Sudan III. The conclusion to which the structures observed point is that this is a region of connective tissue, which has become infiltrated with some pathological product, and has acquired the thick capsule in consequence of its abnormal condition. The infiltrating material is very varied, in some parts it takes magenta brilliantly, while in others it stains in a very faint manner. The more brilliantly coloured tissue appears more homogeneous than that which refuses to take the stain. The colour of the capsule is dark brownish-grey, that of the contents a deep cream (fig. 2, No. 1).

(*b*) There are numerous roundish glandular objects embedded in the fat which lies in the mid-dorsal region of the body cavity of the Finner and surrounds the great vessels. These are lymphatic glands. One such specimen preserved is of very irregular shape. It is 1¾ in. in greatest length and 1½ in. in greatest breadth (fig. 2, No. 2).

[9] *Trans. Conn. Acad. of Arts and Sciences*, Vol. 5, Pt. 1, p. 197 (1880).

(*c*) A number of greenish bodies were taken from a similar position in the Sperm Whale. The specimens are about 2½ in. long, about 2 in. wide, and ¾ in. thick, at the thickest part. The histological condition is exceedingly bad, as was to be expected from the general state of all the Sperm Whales which we saw. There is a connective-tissue capsule, and a great mass of the body is composed of the same tissue. There are two or three objects which may be sections of medullated nerves, and a number of rather thick-walled blood-vessels. No other structures can be recognised.

(*d*) The rectum of *Physeter* has an exceedingly well-developed cuticular lining for the last four or six feet of its length. In the

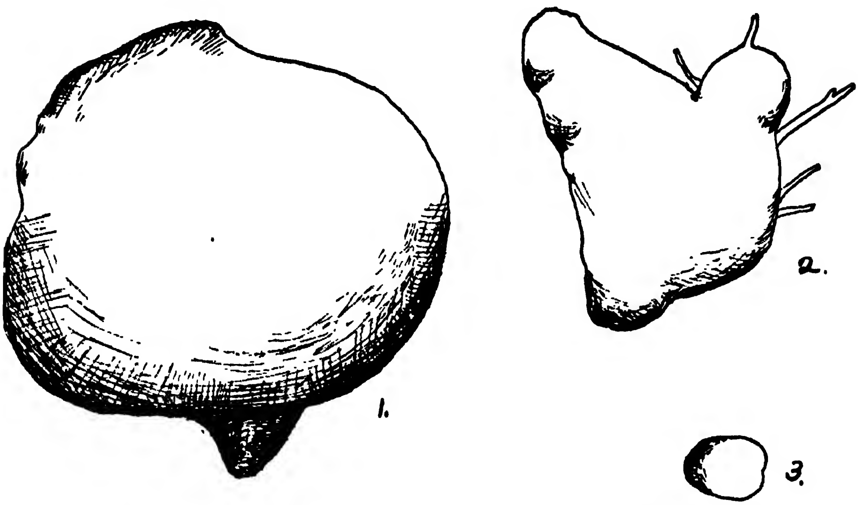


Fig. 2.—1. Calcified Body, from Finner No. 5. 2. Lymphatic Gland, Finner. 3. Cysticercus, from *Physeter*. (All natural size.)

first specimen in which it was observed the lining was detached owing to decomposition, but in a later example it was found to be attached to the remainder of the intestinal wall. This lining is about ⅛ in. thick. It has a pale yellow colour, and is of a consistency somewhat resembling that of a very hard-boiled egg. It is laminated, and can be readily split into layers. At irregular distances on the surface are hollows, penetrating partly or completely through the lining. The edges of these hollows have a puckered appearance. The line of junction of this lining with the mucosa of the intestine is perfectly sharp. The lining thins out very much just prior to its cessation, and the edges of successive laminæ are readily observed. The actual thickness of the lining where it comes to an end is $\frac{1}{16}$ in. The colour of the mucous membrane, which is fairly tough, is a dull pink, very much stained with sepia. Longitudinal sections of this region at the point of junction clearly show that this is a cuticle derived from the stratified epithelium of the rectum. The cuticle comes to a very abrupt termination, where it joins the mucosa, the line of

junction being very obvious in the slides. The epithelial layer is about half as thick as the cuticular.

VII.—*Parasites.*

1. External.

(*a*) *Balænophilus unisetus* (Aurivillius). We have nothing to add to Burfield's remarks on this species.[10]

(*b*) *Penella* (Kov. and Dan.). This parasite was observed on few of the whales examined, and only on the Finner. Three specimens were preserved, which vary in length from $5\frac{3}{4}$ in. to 10 in. No males were found as a result of the examination of these females. We frequently found white scars upon the skin of *B. musculus*, which were apparently healed wounds caused by *Penella*. The scars took the form of small oval marks about $\frac{3}{16}$ in. long and $\frac{1}{8}$ in. wide. Beneath the white area the epidermis is more firmly adherent than in other parts of a preserved specimen, which supports the view that these are healed wounds. We often found open wounds on the whales, which had evidently been produced by this parasite.

All the *Penella* which we saw occurred at the beginning of the season, and in the latter part of it only wounds from which the Copepods had fallen were observed. It may therefore be suggested that the period of attachment of the parasite to the whale is less than a year.

(*c*) *Coronula diadema* (L.), &c. On the Humpback there were large quantities of this species on the tips and especially on the posterior margins of the flippers. They were also found on the ventral furrows, and some small specimens were adhering behind the penis.

A number of specimens of *Conchoderma aurita* (L.) occurred among the *Coronula*, as well as a good number of small specimens of *Cyamus*, which last parasite was also generally scattered over the head region. On *Physeter* No. 15 four specimens of *Cyamus* were also found on the throat region, where there are a few short wrinkles. On the tip of the lower jaw of Sperm Whale No. 16 there was a small colony of *Conchoderma aurita*, while another specimen of the same species was taken from the second tooth of the left side of the lower jaw of Sperm Whale No. 25.

2. Internal.

(*a*) *Trematodes.*—*Monostomum plicatum* (Creplin) was found in the intestines of the following Finners: 1, 3, 19, 23, 24, 27, 30.

(*b*) *Nematodes.*—We found nematodes, which appear to be of the genus *Ascaris*, in the stomachs of every Sperm Whale examined. They are generally very abundant. In the renal vein of the *Megaptera* the mass of nematodes described later was found, and in the posterior vena cava of *B. sibbaldii*, No. 33, a solitary, incomplete specimen of another nematode was taken. These worms all appear to belong to the Strongylidæ. As mentioned later, in the digitate structure observed in the veins of *B. musculus* nematode eggs were found, as was also

[10] *Op. cit.*, p. 179.

the case in the neighbourhood of the mass of the worms found in the Humpback.

(*c*) *Acanthocephali.*[11] Representatives of this group were found in every species except *B. borealis.*

B. musculus,	*Echinorhynchus*	*porrigens* (Rudolphi), new host.
B. sibbaldii	,,	*porrigens* in small intestine, new host.
,,	,,	*brevicollis* (Malm).
M. longimana	,,	*porrigens*, large intestine.
P. macrocephalus	,,	*capitatus* (von Linstow), new host.
,,	,,	*brevicollis* (Malm).

(*d*) *Cestodes.*—One of the Norwegians drew our attention to a large number of soft white bodies embedded in the blubber of one of the Sperm Whales. They occurred in a more or less irregular manner at a depth of from 1½ to 6 in. from the outer surface. Each body is enclosed in a cyst with fibrous walls from which it is readily detached. The accompanying figure (fig. 2, No. 3) is taken from a specimen in good condition and undistorted. Sections of these bodies clearly demonstrate that they are the cysticercus stage of some Cestode. The proscolex occurs at one of the poles of the long axis. The Prince of Monaco's account of the capture of a Sperm Whale off the Azores in 1895 mentions numerous cysticerci in the blubber of that animal, which are probably identical with those here described.[12]

(*e*) *Structure found in the renal veins and posterior vena cava* (see figs. 3 and 4).

In whale No. 8 ♂, while searching for the suprarenal, we came across a series of short, digitate processes, hanging into the lumen of the vena cava at the point of entrance of the renal vein. A similar structure occurred in whales Nos. 12 ♂, 13 ♂, 27 ♂, 30 ♀, 32 ♂, all Finners. In two of the Blue Whales, Nos. 17 ♀ and 33 ♀, it was also present, as well as in *Megaptera*, No. 28 ♂, but in the last in a somewhat different form. In some specimens, owing to the manner in which the kidney was cut away from the body in removing the entrails, it was impossible to say whether the structure had been present or not. No trace of it was found in any of the Sperm Whales examined.

The specimens preserved are four in number, all differing from one another. The accompanying figures show the two larger specimens. Fig. 3 is an example of the most digitate form. This specimen is not actually in the renal vein, but projects from the wall of the vena cava close to the point of entrance of the renal vein. The digitate processes are not actually tubular, but contain cavities, which in the free ends are nearly continuous, so that the whole process is here practically a blind sac. The diameter of the processes increases from the free end towards the wall of the vena cava. The digitations unite at the point of attachment, and the structure thus formed is continued beyond the wall of the vein towards the kidney. It is most unfortunate that we were unable to preserve a specimen

[11] *Vide* A. E. Shipley, *Archives de Parasitologie*, II., No. 2, p. 262, 1899.
[12] *Bull. Mus. Nat. Hist., Paris*, t. 1, p. 308, 1895.

sufficiently large to show whether there is an actual connection with the kidney itself. But from notes taken at the Station, I find that in one of the Blue Whales this structure was followed up, and that branches of the renal vein were found blocked by it in the proximal region of the kidney. This was also the case in the Humpback, No. 28.

The interior of the digitations shows the cavities above mentioned, separated from each other by walls of connective tissue continuous with the tissue of the walls of the tube In section the wall is seen to be composed of fibrous connective tissue very dense externally, but more open in the inner layers, where there are also some nodules of lymphoid tissue. The partitions between adjacent cavities come off from the inner layers of the outer wall. There are a few blood-vessels in these structures. The cavities are filled with material which varies in consistency from that of a rather stiff pulp to a stony hardness. In the latter case the material contains a varying amount of inorganic salts, chiefly calcium phosphate, of which there may be as much as 80 per cent. present. These concretions are very hard in the fully calcified condition, and are rounded in form in the Finners, but more rod-like in specimens taken from a Blue Whale and the Humpback. The soft material varies in its composition. In its softest state it is easily teased out in water, and is then seen to be composed of a mass of nematode eggs. Although the shells are very thick, and resist the action of pure nitric acid and of strong alkali, they are very transparent, and embryos may be seen in their interiors in stages of development varying from morula-like masses to small coiled worms. In the partially calcified material it is still possible to separate by teasing numbers of these ova, which are here covered with the calcium deposit. On the application of mineral acid the inorganic material dissolves away, leaving the ova distinctly recognisable as such.

Fig. 4 shows a specimen which is confined to the renal vein, and has no digitations hanging into the vena cava. There is a single cylindrical body about 6 in. long attached to the wall of the renal vein by strap-like bands of varying breadth tapering somewhat towards their junctions with the body. Sections of this body show the thick wall, partitions, and congregations of ova, as described above. The ova appear to be embedded in a matrix nearly homogeneous, but containing numerous small rounded bodies, which stain darkly with Ehrlich's hæmatoxylin. They may be nuclei, and in that case indicate that the matrix is probably cellular. In the renal vein of *Megaptera* a mass of tissue was found of an elongated form, and containing hard calcareous material together with a number of tangled nematode worms, which appear to belong to the family Strongylidæ. The worms were mostly enveloped in sheathing tissue attached to the wall of the vein, but the sheath was not always complete.

There can be little doubt that the presence of these worms affords the key to the formation of the growths described above. It is known that the presence in a vein of any object the surface of which is not smooth, or of lesions of the intima of a blood-vessel, produces

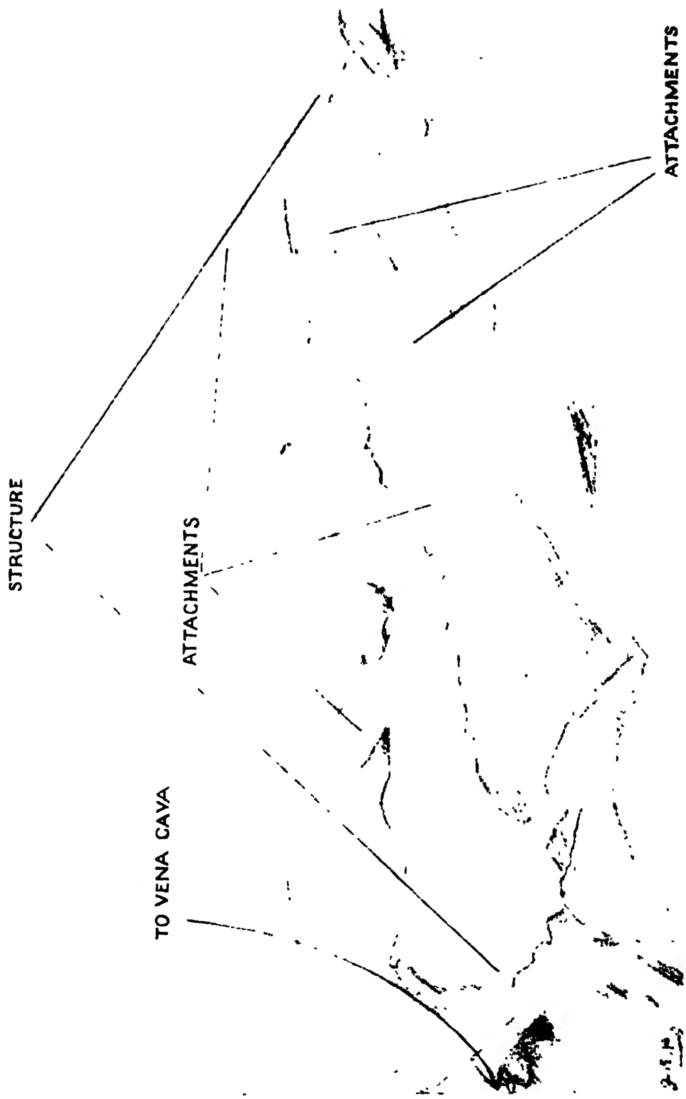


FIG. 4.—Renal Vein opened, showing Enclosed Structure caused by Nematodes. Slightly foreshortened. Circ. ½.

Illustrating the Report on Belmullet Whaling Station.

[*To face page* 142.

a thrombus, which may in the course of time become organised.[13] The organisation takes the form of a proliferation of the fibrous tissue of the blood-vessel wall, which in the course of time entirely replaces the thrombus. This tissue may be supplied with blood-vessels. Thrombi may become calcified, and the deposition of calcium salts is one of the striking features of the structures under consideration. Again, metazoan parasites have been known to cause thrombi,[14] and in the cases before us it is highly probable that the nematodes have produced vascular lesion, or the mere presence of the eggs may have been sufficient to excite coagulation of the blood. From either of these causes the thrombi may have been formed, becoming subsequently organised. It is interesting to note in this connection that pedunculated, if not digitated, thrombi have occurred in the human subject. The thrombus in *Megaptera* appears to have actually *enclosed* the worms which caused it, and they have been retained by the subsequent organisation.

VIII.—*Fœtuses.*

B. musculus.—None of the fœtuses examined by us were sufficiently small to be of use for embryological purposes. They were all perfectly formed, and even in the smallest (3 ft. 11 in.) the ventral furrows of the adult were represented by mere lines.

Table VI. contains a list of the fœtuses, and a detailed list of measurements will be found in Table XII. It may be noted that the 8 ft. fœtus of No. 30 was mutilated by some of the workers before we arrived on the scene, while that of No. 31 was destroyed before the female was opened, apparently by the harpoon explosion. The sizes of both of these are therefore estimates only. The fœtus of No. 47 (9 ft. 4 in.) was in a hopeless state of decomposition, and very few measurements could be taken upon it.

(*a*) *Body form.*—In all the fœtuses which we saw the form was the same as in the adult, but in the smallest it was noticeably more robust.

(*b*) *Colouration.*—This character does not differ from that of the adult animals. The dark tint is found in the same situations. The smaller fœtuses are very much less pigmented. In the 3 ft. 11 in. fœtus the whole skin was gorged with blood, and the black colour was confined to the following localities: back, tip of dorsal fin, tip of flippers, tips of flukes, tip of rostrum, and symphysis.

B. sibbaldii.—One specimen, 7 ft. 7 in. in length, was seen. The upper surface was pale grey, the distal part of the dorsal fin and the external mouth parts were stained with black.

IX.—*Breeding Season of the Balænopterids.*

A factor which may be used in attempting to ascertain the probable breeding season of the large whales is the sizes of the fœtuses observed at different times. Leaving for this purpose the Blue Whale out of

[13] Macfarlane, *Text Book of Pathology*, 1904 ed., pp. 107-8. Green, *Manual of Pathology*, 11th ed., p. 66.
[14] Green, *op. cit.*, p. 389.

account, because very few of this species have been seen in the pregnant condition, the six fœtuses which we saw have the following dimensions:

		Ft.	in.
July	15	15	0
Aug.	7	8	0
„	7	4	0
„	27	7	10
Sept.	4	3	11
„	9	9	4

Burfield's table of fœtuses observed in 1911 is as follows:—

		Ft.	in.
July	12	8	11
„	16	4	11
„	20	8	5
„	24	6	0
Aug.	7	5	6
„	11	9	0
Sept.	10	9	0
„	18	9	3

The young whale appears to be about 20 ft. long when born. If the size of the fœtus is proportional to the length of gestation which has elapsed since pairing until the time when the fœtus is measured, and if the period of gestation is ten months,[15] then the fœtuses found must have been the result of pairings at approximately the times given opposite each in the table which follows:—

		Ft.	in.				
July	15	15	0	age	7½	months, pairing took place	December-January.
Aug.	7	8	0	„	4	„ „ „	April (beginning).
„	7	4	0	„	2	„ „ „	June.
„	27	7	10	„	4	„ „ „	April (end).
Sept.	4	3	11	„	2	„ „ „	July (beginning).
„	9	9	4	„	5	„ „ „	May.

Pursuing the same idea with the 1911 fœtuses, we have:—

		Ft.	in.				
July	12	8	11	age	4½	months, pairing took place	March (beginning).
„	16	4	11	„	2½	„ „ „	May (beginning).
„	20	8	5	„	4½	„ „ „	March (beginning).
„	21	6	0	„	3	„ „ „	April (end).
Aug.	7	5	6	„	3	„ „ „	May.
„	11	9	0	„	5	„ „ „	March April.
Sept.	10	9	0	„	5	„ „ „	May (beginning).
„	18	9	3	„	5	„ „ „	May.

These times can only be regarded as approximate, even if the premises upon which they are based be correct. It is, however, suggested by this table that pairing may take place at any time between the end of December (the first in the 1913 series) and the beginning of July (fifth in the 1913 table), at intervals of roughly two months. This would indicate that the Balænopterids are, at any rate, polyœstrous, and in season in December (February?), April, and June. All females would not be fit for breeding actually simultaneously, but the precise time would vary for different individuals, and

[15] Burfield, *op. cit.*, p. 155.

this would account for some pairings occurring at such times as the beginning of July or the beginning of May.

Such cases would belong to the June and April œstra respectively. It is probable that such an arrangement would be advantageous. As the whale is a pelagic animal and individuals are widely separated, a frequently recurring breeding condition would be of great advantage to an animal in which pairing is to a greater or less extent casual. The above suggestion, which was originated by Mr. Daniel, appears to afford a possible explanation of the extraordinary variability in the sizes of the fœtuses, apparently without regard to the season, a circumstance which the idea of a definite monœstrous condition does not elucidate. (It is interesting to note that on June 13, 1913, at the Inishkea Station a fœtus only 5 in. long was found, which must have been but a week or two old, *i.e.*, of the June pairing, according to the preceding method of reckoning the pairing times. It was, most unfortunately, not possible to preserve it.)

X.—*Additional Notes.*

(*a*) *Extinction.*—The whalemen state that of the whales which they see they are able to take only about one in ten. The animals are therefore perhaps not in immediate danger of being actually killed out. The most serious risk lies in the fact that the largest, and therefore the adult, whales are being exterminated. True gives as the minimum length of adult animals 55 ft. 7 in., as no pregnant females of less dimensions have been recorded. Now the whalers will take *anything* over 40 ft., with the result that the animals which have attained sexual maturity are in the gravest danger of being killed out. That the largest whales *are* being exterminated, the fall in general size at Blacksod between 1911 and 1913 may indicate. This means that the whales which are capable of reproduction are being destroyed. By the time that it is no longer profitable to hunt whales,[16] it appears likely that the adults will have been so thinned out that they will no longer be able to reproduce with sufficient profusion to compensate for natural casualties. When this occurs the whales will be well within sight of extinction.

(*b*) *Capture of Blue Whales.*—Of all the species which it is profitable to pursue the whalers state that the Blue Whale is the wildest, and they will not hunt this species if other game is to be had. A Blue Whale on perceiving the pulsations of the propeller of the approaching steamer is usually startled, and, if alarmed, at once rushes off at full speed. Since this represents something like twenty miles per hour, it is quite useless for the boat to pursue the fleeing animal, the speed of the steamer being only ten or twelve miles per hour. When the whalers are bent on catching a Blue Whale, it is sometimes necessary to accompany the animal for three or four days, until it becomes accustomed to the presence of the steamer, which can then approach within range, and the whale is speedily disillusioned as to the harmlessness of the now familiar object.

(*c*) *Migration Movements.*—During the earlier part of the season the Mystacocetes are stated to travel in a north-easterly direction,

[16] Burfield, *op. cit.*, p. 153.

during the later part in a south-westerly. If this be so, it may be concluded that the latter is the return journey of those whales which have passed north in the beginning of the season.

The solitary Humpback, taken on July 25, was moving in a direction the reverse of that which the Finners and Blue Whales were pursuing at the same time.

The only Sejhval which was captured was brought in on September 6, a fact which is to be noted in connection with the whalers' statement to Burfield,[17] that the Sejhval disappears by the end of June.

The following is the explanation which the whalers give of the occurrence of Sperm Whales in these Northern waters. In the Southern seas each adult male is the leader of a herd of females, and as the young bulls approach maturity they are driven off by the old leader. These young bulls do not become leaders of herds, as they are inferior in strength and size to the fully adult males. But when fully grown they seek out herds, and contend with the leaders for the possession of the females. If the old males are then driven off, they become solitary wanderers, and frequently travel up into the North Atlantic. In connection with this theory it may be mentioned that the Sperm Whales taken at Blacksod and Inishkea are all males, and of great size for Sperm Whales, which seldom exceed 60 ft., the average for the ten Blacksod specimens being 57 ft. $3\frac{1}{2}$ in., while the smallest was 53 ft.

TABLE I.—*B. musculus.* Table of Specimens Taken.

Number of Whale	Date when Measured	Sex	Total Length Ft.	in.	Number of Whale	Date when Measured	Sex	Total Length Ft.	in.
—	May 16	—	59	6	14	July 5	[illegible]	54	7
—	„ 28	—	62	6	18	„ 11	[illegible]	59	4
—	„ 31	—	59	6	19	„ 15	[illegible]	67	3
—	June 14	—	61	6	20	„ 15	♂	59	3
—	„ 19	—	61	0	23	„ 20	[illegible]	48	7
—	„ 20	—	53	0	24	„ 20	[illegible]	53	7
—	„ 21	—	68	6	27	„ 25	♂	66	0
—	„ 22	—	61	6	29	Aug. 5	♀	57	5
—	„ 22	—	64	6	30	„ 7	♀	69	8
—	„ 22	—	64	6	31	„ 7	♀	65	0
—	„ 23	—	64	6	32	„ 16	♂	57	7
1	„ 26	♀	69	4	35	„ 27	♀	63	3
2	„ 26	[illegible]	50	7	36	„ 28	♂	58	5
3	„ 28	♂	64	1	37	„ 29	♀	62	3
4	„ 28	♂	63	1	38	„ 29	♀	55	2
5	„ 30	♂	64	0	39	„ 30	♂	58	3
6	„ 30	♀	66	9	40	„ 30	♀	60	8
7	July 2	♂	61	0	41	Sept. 1	♂	56	2
8	„ 2	♂	62	0	42	„ 2	♂	61	6
9	„ 3	♂	60	0	43	„ 4	♀	59	10
10	„ 3	♂	55	2	44	„ 5	♂	52	10
11	„ 3	♂	58	1	45	„ 5	♂	58	0
12	„ 4	♂	55	0	47	„ 8	♀	62	8
13	„ 4	♂	46	7	48	„ 8	♂	63	5

[17] *Op. cit.*, p. 154.

TABLE II.—*B. sibbaldii.* List of Specimens.

Number of Whale	Date when Measured	Sex	Total Length		Number of Whale	Date when Measured	Sex	Total Length	
			Ft.	in.				Ft.	in.
17	July 10	♀	78	2	34	Aug. 20	♀	68	6
33	Aug. 18	♀	70	7	49	Sept. 9	♀	68	0

TABLE III.—*B. borealis.* One Specimen.

Number of Whale	Date when Measured	Sex	Total Length Ft.	in.
46	Sept. 6	♀	46	7

TABLE IV.—*M. longimana.* One Specimen.

Number of Whale	Date when Measured	Sex	Total Length Ft.	in.
28	July 25	♂	45	8

TABLE V.—*Physeter macrocephalus.* List of Specimens Taken.

Number of Whale	Date when Measured	Sex	Total Length		Number of Whale	Date when Measured	Sex	Total Length	
			Ft.	in.				Ft.	in.
—	May 26	♂	57	9	16	July 9	♂	56	3
—	,, 26	♂	61	4	21	,, 16	♂	60	6
—	,, 31	♂	62	6	22	,, 18	♂	57	3
—	June 14	♂	60	5	25	,, 23	♂	53	0
15	July 8	♂	57	5	26	,, 25	♂	56	2

TABLE VI.—Fœtuses. *B. musculus.*

No. of Parent	Date when Measured	Sex	Total Length	
			Ft.	in.
19	July 15	♂	15	0
30	Aug. 7	♀ ?	8	0 (circ.)
31	,, 7	—	4	0 (circ.)
35	,, 27	♀	7	10
43	Sept. 4	♂	3	11
47	,, 8	♂	9	4

TABLE VII.—*B. sibbaldii.* One fœtus.

No. of Parent	Date when Measured	Sex	Total Length Ft.	in.
33	Aug. 18	♂	8	0

TABLE VIII.—*B. musculus.* Measurements.

Number of Whale	No. 1 ♀		No. 2 ♀		No. 3 ♂		No. 4 ♂		No. 5 ♂		No. 6 ♂		No. 7 ♂		No. 8 ♂		No. 9 ♂		No. 10 ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	69	4	50	7	64	1	63	1	64	0	66	9	61	0	62	0	60	0	58	1
Tip of snout to spiracle	—		—		—		—		9	4	11	0	8	8	10	4	9	4	9	0
Tip of snout to posterior insertion of pectoral fin	—		—		25	5	20	0	20	11	21	6	17	9	20	7	18	10	18	2
Tip of snout to posterior insertion of dorsal fin	—		47?	7?	43	4	43	9	43	0	—		45	0	48	8	46	4	44	9
Tip of snout to centre of eye	—		—		13	3	13	0	—		13	7	11	0	12	7	11	1	11	1
Symphysis of jaw to centre of eye	—		—		—		—		—		16	6	12	10	16	5	14	6	13	1
Centre of eye to anterior end of ear aperture	—		—		2	4	3	4	2	11	3	6	2	9	3	6	2	9	2	8
Notch of flukes to posterior end of anus	—		13	1	12	4	11	0	16	4	18	6	16	5	17	9	17	1	15	8
Notch of flukes to anterior margin of umbilicus	—		(to posterior umbilicus) 26	4	28	4	24	1	28	6	30	6	26	0	29	9	28	10	26	2
Length of pectoral fin, tip to anterior insertion	—		—		7	10	—		7	4	7	7	6	10	8	3	7	4	7	2
Length of pectoral fin, tip to posterior insertion	—						—		5	3	5	4	5	2	5	7	5	2	4	7
Median length of pectoral fin	—		—		6	3	—		—		6	2	6	0	7	3	6	0	5	9
Pectoral fin, greatest breadth	—		—		1	4	1	8½	1	5	1	10	1	5	—		1	8	—	
Dorsal fin, length	4	10	4	6	4	3	4	5	4	8	4	2	3	1	4	2	4	1	2	8
Dorsal fin, vertical height	1	4	1	5	1	7	1	6	1	3	1	7	1	5	1	8	1	6	1	5
Number of ventral furrows	—		—		—		—		54		68		76		70		—		67	

TABLE VIII.—*B. musculus.* Measurements (*continued*).

Number of Whale	No. 11 ♂		No. 12 ♂		No. 13 ♂		No. 14 —		No. 18 —		No. 19 ♀		No. 20 ♂		No. 23 ♀		No. 24 ♀		No. 27 ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	55	2	55	0	46	7	54	7	59	4	67	3	59	0	48	7	53	7	66	0
Tip of snout to spiracle	9	2	8	9	7	0	8	0	10	3	10	9	9	1	6	7	8	2	9	6
Tip of snout to posterior insertion of pectoral fin	18	10	18	0	14	7	17	11	20	0	23	0	20	0	15	6	17	9	19	7
Tip of snout to posterior insertion of dorsal fin	42	1	42	7	35	7	42	4	46	2	52	8	46	6	36	11	40	10	54	0
Tip of snout to centre of eye	11	1	10	11	8	9	14	0	12	8	13	4	11	6	9	2	11	1	11	10
Symphysis of jaw to centre of eye	12	4	13	1	10	3	12	2	15	9	16	6	13	7	—		12	11	14	1
Centre of eye to anterior end of ear aperture	2	9	2	6	2	7	2	8	3	0	3	1	3	4	2	6	2	9	3	2
Notch of flukes to posterior end of anus	15	8	15	9	12	8	17	4	17	10	19	3	—		14	4	15	3	15	6
Notch of flukes to anterior margin of umbilicus	25	3	27	1	21	11	27	0	28	10	33	1	—		22	7	25	6	25	11
Length of pectoral fin, tip to anterior insertion	6	9	7	3	5	3	—		7	8	7	8	7	0	6	8	7	9	6	4
Length of pectoral fin, tip to posterior insertion	4	9	4	11	4	0	—		5	2	5	2	5	0	4	0	4	7	4	8
Median length of pectoral fin	5	9	6	2	4	7	—		6	0	6	0	6	6	5	10	5	10	5	7
Pectoral fin, greatest width	1	5	1	6	1	3	1	6	1	10	1	0	1	7	1	4	1	6	1	7
Dorsal fin, length	6	9	4	11	2	7	2	3	3	5	3	10	3	0	2	8	2	6	3	2
Dorsal fin, vertical height	1	3	1	4	1	0	1	1	1	5	1	6	1	1	1	2	0	11	1	6
Number of ventral furrows	62		71		65		—		59		68		73		56		77		69	

TABLE VIII.—*B. musculus.* Measurements (*continued*).

Number of Whale	No. 29 ♀		No. 30 ♀		No. 31 ♀		No. 32 ♂		No. 35 ♀		No. 36 ♂		No. 37 ♀		No. 38 ♀		No. 39 ♂		No. 40 ♀	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	57	5	69	8	65	0	57	7	63	3	58	5	62	3	55	2	58	3	60	8
Tip of snout to spiracle	9	11	12	2	11	2	9	6	10	0	9	1	11	1	9	7	9	8	9	8
Tip of snout to posterior insertion of pectoral fin	18	4	21	9	21	3	18	9	18	11	18	3	20	6	18	2	19	2	19	10
Tip of snout to posterior insertion of dorsal fin	45	1	54	6	56	3	44	3	46	3	45	9	48	0	42	3	44	10	45	7
Tip of snout to centre of eye	11	11	13	0	13	1	11	1	12	1	—		12	5	—		12	1	11	8
Symphysis of jaw to centre of eye	—		15	10	15	3	—		13	11	—		15	0	—		14	5	13	10
Centre of eye to anterior end of ear aperture	2	8	3	1	2	11	2	4	3	4	2	7	3	4	2	7	2	11	2	10
Notch of flukes to posterior margin of anus	15	6	19	5	18	0	16	4	16	4	1	0	17	5	15	3	16	11	17	0
Notch of flukes to anterior margin of umbilicus	26	3	30	10	29	5	27	8	27	0	—		28	9	25	8	28	1	29	2
Length of pectoral fin, tip to anterior insertion	6	6	7	8	6	4	—		7	5	7	8	8	0	8	0	6	10	6	10
Length of pectoral fin, tip to posterior insertion	5	3	5	8	5	10	—		5	5	4	9½	5	9	5	0	4	9	4	9
Median length of pectoral fin	5	6	6	8	5	1	—		6	4	5	7	6	10	6	0	5	7	5	5
Pectoral fin, greatest breadth	1	9	1	9	1	9	—		1	10	1	7	1	9	1	5	1	7	1	7
Dorsal fin, length	—		3	7	3	3	3	6	4	11	3	6	2	5	3	8	4	4	3	0
Dorsal fin, vertical height	—		2	1	1	2	1	4	1	9	1	2	1	2	1	1	1	5	1	6
Number of ventral furrows	67		61		84		—		59		—		—		62		63		64	

TABLE VIII.—*B. musculus.* Measurements (*continued*).

Number of Whale	No. 41 ♂		No. 42 ♂		No. 43 ♀		No. 44 ♂		No. 45 ♂		No. 47 ♀		No. 48 ♂	
	Ft.	in.	Ft.	in	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	56	2	61	6	59	10	52	10	58	0	62	8	63	5
Tip of snout to spiracle	9	5	9	10	9	10	8	9	9	10	9	11	11	0
Tip of snout to posterior insertion of pectoral fin	18	3	19	9	18	6	17	9	19	2	20	8	21	7
Tip of snout to posterior insertion of dorsal fin	42	11	47	10	47	6	41	7	46	1	47	9	49	3
Tip of snout to centre of eye	12	0	11	8	11	10	10	5	11	10	12	1	12	11
Symphysis of jaw to centre of eye	14	2	14	3	14	2	12	8	14	3	14	6	—	
Centre of eye to anterior end of ear aperture	2	8	3	2	2	10	2	9	2	10	2	10	3	0
Notch of flukes to posterior margin of anus	15	9	14	11	16	9	14	7	15	8	17	9	17	9
Notch of flukes to anterior margin of umbilicus	26	7	27	4	28	5	24	6	27	0	29	10	29	0
Length of pectoral fin, tip to anterior insertion	6	6	7	5	7	9	6	6	7	3	8	1	—	
Length of pectoral fin, tip to posterior insertion	4	8	5	3	4	11	4	4	4	8	5	8	—	
Median length of pectoral fin	5	4	6	6	6	6	5	11	6	5	6	8	—	
Pectoral fin, greatest breadth	1	5	1	9	1	8	1	6	1	7	1	9	—	
Dorsal fin, length	3	0	3	7	3	2	3	7	4	0	3	9	3	6
Dorsal fin, vertical height	1	3	1	3	1	3	1	6	1	7	1	10	1	2
Number of ventral furrows	75		61		65		—		64		64		65	

Measurements.—TABLE IX. *B. sibbaldii.* TABLE X. *B. borealis.* TABLE XI. *Megaptera longimana.*

Number of Whale	No. 17 I. ♀		No. 33 II. ♀		No. 34 III. [illegible]		No. 49 IV. ♀		No. 46 I. ♀		No. 38 I. ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	78	2	70	7	68	6	68	0	46	7	45	8
Tip of snout to spiracle	12	6	12	3	12	5	11	0	7	8	7	11
Tip of snout to posterior insertion of pectoral fin	27	9	24	0	24	2	21	10	15	9	16	5
Tip of snout to posterior insertion of dorsal fin	67	6	55	6	53	3	52	0	32	10	30	10
Tip of snout to centre of eye	16	2	15	2	14	10	13	6	9	6	11	11
Symphysis of jaw to centre of eye	20	2	18	0	17	10	16	5	11	7	13	6
Centre of eye to anterior end of ear aperture	—		3	3	3	7	3	4	2	5½	2	7¼
Notch of flukes to posterior margin of anus	22	3	19	6	19	7	19	5	12	2	10	11
Notch of flukes to anterior margin of umbilicus	35	7	32	6	30	11	31	8	21	11	18	7
Length of pectoral fin, tip to anterior insertion	11	0	11	10	11	6	11	0	6	8	14	4
Length of pectoral fin, tip to posterior insertion	7	7	7	10	8	0	7	8	4	8	12	0
Median length of pectoral fin	8	9	9	0	9	9	8	10	5	9	12	9
Pectoral fin, greatest breadth	3	0	2	7	2	9	2	6	1	3½	3	4
Dorsal fin, length	3	1	2	4	2	11	2	8	2	10	4	8
Dorsal fin, vertical height	0	10	0	7½	0	8	0	11	2	1	1	5
Number of ventral furrows	69		73		60		64		47		23	

TABLE XII.—*Physeter macrocephalus*.—Measurements.

Number of Whale	No. 15 I. ♂		No. 16 II. ♂		No. 21 III. ♂		No. 22 IV. ♂		No. 25 V. ♂		No. 26 VI. ♂	
	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
Total length	57	5	56	3	60	6	57	3	53	0	56	2
Front of snout to posterior pectoral	24	0	24	2	25	3	22	9	21	9	24	6
Front of snout to posterior dorsal	40	0	39	3	41	9	38	3	37	8	—	
Tip of upper jaw to angle of mouth	—		10	0	10	11	10	11	11	5	11	1
Tip of lower jaw to angle of mouth	10	3	9	9	10	5	10	8	11	9(?)	11	0
Notch of flukes to posterior margin of anus	—		15	9	17	9	16	2	12	6	15	4
Notch of flukes to anterior margin of umbilicus	(anus to umbilicus) 12	0	26	2	27	6	26	11	22	9	—	
Length of pectoral fin, tip to anterior insertion	5	3	5	1	4	10	4	7	4	0	4	9
Length of pectoral fin, tip to posterior insertion	4	0	3	3	3	6	2	3	1	8	1	9
Median length of pectoral fin	4	9	4	1	3	8	3	6	3	6	4	0
Pectoral fin, greatest breadth	2	9	2	6	3	1	2	7	2	5	2	6
Dorsal fin, length	4	4	5	0	4	5	6	3	4	6	6	0
Dorsal fin, vertical height	1	2	1	2	1	10	1	3	1	6	1	4
Length of head, dorsal	—		—		21	10	—		18	10	20	0
Half circumference, just behind mouth	15	2	15	9	—		—		—		—	
Height of head, at anterior end of mouth	10	0	—		10	11	—		8	1	9	3
Width of snout	5	3	—		5	3	—		4	7	5	3

Measurements.—Fœtuses.—TABLE XIII. *B. musculus.* TABLE XIV. *B. sibbaldii.*

Number of Parent	No. 19	No. 30	No. 35	No. 43	No. 47	No. 33
Sex of Fœtus	♂	♀	♀	♂	♂	♂
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	15 0	—	7 10	3 11	9 4	7 7
Tip of snout to spiracle	1 ·11	—	1 0¾	0 6	—	1 0½
Tip of snout to posterior insertion of pectoral fin	4 6	3 6¾	2 4½	1 3	—	2 7
Tip of snout to posterior insertion of dorsal fin	11 2	—	6 0	2 11	—	5 10½
Tip of snout to centre of eye	2 8	2 2	1 5¼	0 8⅜	—	1 5
Symphysis of jaw to centre of eye	3 1	—	1 7¾	0 9¾	—	1 7
Centre of eye to anterior end of ear aperture	—	0 8	0 5½	0 3¼	—	0 6¼
Notch of flukes to posterior margin of anus	4 3½	—	2 2	1 1⅜	—	2 5
Notch of flukes to anterior margin of umbilicus	6 9	—	3 7¼	1 9⅜	—	3 8
Length of pectoral fin, tip to anterior insertion	2 4	1 10	1 1	0 6	1 2	1 4
Length of pectoral fin, tip to posterior insertion	1 8	1 2¾	0 8½	0 4½	0 11	0 10¾
Median length of pectoral fin	1 10½	1 6¾	0 10	0 5	1 1	1 0¾
Pectoral fin, greatest breadth	0 6¼	0 4¾	0 2¾	0 1⅜	0 3½	0 3¾
Dorsal fin, length	1 6	—	0 6	0 1⅝	0 7	0 4½
Dorsal fin, vertical height	0 5	—	0 3¼	0 1	0 3½	0 1
Width of flukes, tip to tip	3 6½	3 2½	1 9¾	0 9	—	1 11
Number of ventral furrows	73	71	49	52	—	83

TABLE XV.—*B. musculus*. Proportions.*

Number of Whale	No. 1 ♀	No. 2 ♀	No. 3 ♂	No. 4 ♂	No. 5 ♂	No. 6 ♀	No. 7 ♂	No. 8 ♂	No. 9 ♂	No. 1 ♂
Total length	Ft. in. 69 4	Ft. in. 50 7	Ft. in. 64 1	Ft. in. 63 1	Ft. in. 64 0	Ft. in. 66 9	Ft. in. 61 0	Ft. in. 62 0	Ft. in. 60 0	Ft. 58
	%	%	%	%	%	%	%	%	%	%
Tip of snout to spiracle	—	—	—	—	14·53	16·48	14·21	16·29	15·55	15·5
Tip of snout to posterior insertion of pectoral fin	—	—	39·42	26·36	32·68	32·21	29·1	33·20	31·39	31·2
Tip of snout to posterior insertion of dorsal fin	—	—	67·62	69·36	67·17	—	73·77	78·48	77·23	77·0
Tip of snout to centre of eye	—	—	20·67	20·61	—	20·35	18·03	20·56	18·48	19·0
Symphysis of jaw to centre of eye	—	—	—	—	—	24·78	21·04	26·48	24·16	24·5
Centre of eye to anterior end of ear aperture	—	—	3·64	5·28	4·56	5·24	4·78	5·64	4·58	4·5
Notch of flukes to posterior end of anus	—	26·19	19·25	17·44	25·52	24·73	26·92	28·64	28·47	26·9
Notch of flukes to anterior margin of umbilicus	—	43·82	44·21	38·74	44·52	45·69	42·62	48·26	48·06	45·0
Length of pectoral fin, tip to anterior insertion	—	—	12·23	—	11·46	11·36	11·20	13·30	12·23	12·3
Length of pectoral fin, tip to posterior insertion	—	—	—	—	8·20	7·81	8·47	9·00	8·61	7·8
Median length of pect. fin	—	—	9·75	—	—	9·24	9·61	11·69	10·00	9·9
Pectoral fin, greatest [illegible]	—	—	2·08	2·70	2·21	2·74	2·32	—	2·77	—
Dorsal fin, length	7·28	—	6·63	7·00	7·29	6·24	4·94	6·72	6·80	4·5
Dorsal fin, vertical height	2·1	—	2·47	2·37	1·95	2·37	2·32	2·68	2·50	2·4
Number of ventral furrows	—	—	—	—	54	68	76	70	—	67

* Proportions = measurements reduced to percentages of total length.

TABLE XV.—*B. musculus.* Proportions (*continued*).

Number of Whale	No. 11 ♂	No. 12 ♂	No. 13 ♂	No. 14 ♀	No. 18 ♀	No. 19 ♀	No. 20 ♂	No. 23 ♀	No. 24	No. 27 ♂
Total length	Ft. in. 55 2	Ft. in. 55 0	Ft. in. 46 7	Ft. in. 54 7	Ft. in. 59 4	Ft. in. 67 3	Ft. in. 59 0	Ft. in. 48 7	Ft. in. 53 7	Ft. in. 66 0
Tip of snout to spiracle	% 16·65	% 15·92	% 13·23	% 14·66	% 17·06	% 15·99	% 15·39	% 13·80	% 15·24	% 14·40
Tip of snout to posterior insertion of pectoral fin	34·14	32·73	31·3	32·83	33·7	34·20	33·9	30·18	33·13	29·68
Tip of snout to posterior insertion of dorsal fin	76·28	77·53	76·38	77·57	77·8	78·30	78·81	71·86	76·21	81·83
Tip of snout to centre of eye	20·09	19·86	18·78	—	21·34	19·83	19·49	18·87	20·68	17·93
Symphysis of jaw to centre of eye	22·36	23·70	22·01	25·65	29·91	24·53	23·02	—	19·14	21·34
Centre of eye to anterior end of ear aperture	4·87	4·53	5·54	4·89	5·05	4·58	5·65	5·14	5·13	4·79
Notch of flukes to posterior end of anus	26·59	28·64	27·19	31·77	33·43	28·49	—	31·61	28·46	23·98
Notch of flukes to anterior margin of umbilicus	45·76	49·25	47·06	49·46	42·98	48·07	—	43·05	37·80	39·27
Length of pectoral fin, tip to anterior insertion	10·65	13·18	11·01	—	12·92	9·04	11·87	13·72	14·46	9·89
Length of pectoral fin, tip to posterior insertion	8·61	8·94	8·58	—	8·58	6·10	8·28	8·23	8·53	7·07
Median length of pectoral fin	10·42	11·21	9·84	—	10·11	8·92	11·02	11·10	10·88	8·46
Pectoral fin, greatest breadth	2·56	2·72	1·93	2·74	3·89	2·72	2·68	2·74	2·78	1·54
Dorsal fin, length	4·87	8·94	—	4·23	7·24	5·71	5·08	5·48	4·66	4·79
Dorsal fin, vertical height	2·26	2·42	2·14	1·98	2·38	2·23	1·83	2·31	1·71	2·27
Number of ventral furrows	62	71	65	—	59	68	73	56	77	69

TABLE XV.—*B. musculus.* Proportions (*continued*).

Number of Whale	No. 29 ♀	No. 30 ♀	No. 31 ♀	No. 32 ♂	No. 35 ♀	No. 36 ♂	No. 37 ♀	No. 38 ♀	No. 39 ♂	No. 40 ♀
Total length	Ft. in. 57 5	Ft. in. 69 8	Ft. in. 65 0	Ft. in. 57 7	Ft. in. 63 3	Ft. in. 58 5	Ft. in. 62 3	Ft. in. 55 2	Ft. in. 58 3	Ft. in. 60 8
	%	%	%	%	%	%	%	%	%	%
Tip of snout to spiracle	17·58	17·51	17·4	13·10	15·81	15·50	17·8	17·37	16·6	15·93
Tip of snout to posterior insertion of pectoral fin	35·22	31·29	33·11	27·37	29·90	31·27	32·94	32·18	32·91	32·70
Tip of snout to posterior insertion of dorsal fin	79·91	78·41	87·86	76·85	73·13	78·39	77·11	76·58	76·98	75·15
Tip of snout to centre of eye	21·12	18·70	20·39	19·25	19·11	—	19·95	—	20·75	24·21
Symphysis of jaw to centre of eye	—	25·65	23·77	—	21·96	—	23·38	—	24·75	22·80
Centre of eye to anterior end of ear aperture	4·72	4·43	4·54	4·05	5·27	4·42	5·35	4·68	3·97	4·67
Notch of flukes to posterior margin of anus	—	27·94	28·05	27·78	25·82	—	27·96	27·02	29·05	28·02
Notch of flukes to anterior margin of umbilicus	48·29	44·36	45·84	47·93	42·69	—	46·18	46·52	48·21	49·34
Length of pectoral fin, tip to anterior insertion	11·26	11·04	9·87	—	11·73	13·14	12·85	15·53	11·73	11·27
Length of pectoral fin, tip to posterior insertion	9·30	8·15	9·09	—	8·56	8·21	9·23	9·06	8·15	7·83
Median length of pectoral fin	9·74	12·08	7·92	—	10·01	9·56	10·97	10·87	9·58	8·93
Pectoral fin, greatest breadth	1·62	2·518	2·72	—	2·89	2·71	2·81	2·71	2·61	2·96
Dorsal fin, length	—	5·15	4·04	6·078	7·77	5·99	3·88	6·64	3·31	4·93
Dorsal fin, vertical height	—	2·92	1·81	2·31	2·76	1·99	1·87	1·96	1·86	2·47
Number of ventral furrows	67	61	84	—	59	—	—	62	63	64

TABLE XV.—*B. musculus.* Proportions (*continued*).

Number of Whale	No. 41 ♂	No. 42 ♂	No. 43 ♀	No. 44 ♂	No. 45 ♂	No. 47 ♀	No. 48 ♂
Total length	Ft. in. 56 2	Ft. in. 61 6	Ft. in. 59 10	Ft. in. 52 10	Ft. in. 58 0	Ft. in. 62 8	Ft. in. 63 5
	%	%	%	%	%	%	%
Tip of snout to spiracle	16·77	16·17	16·44	16·56	16·95	15·46	17·31
Tip of snout to posterior insertion of pectoral fin	32·48	32·46	30·93	33·59	33·04	32·98	34·03
Tip of snout to posterior insertion of dorsal fin	76·40	78·68	79·39	78·70	79·45	76·23	77·66
Tip of snout to centre of eye	20·77	19·59	19·78	19·72	20·40	19·29	20·36
Symphysis of jaw to centre of eye	24·62	26·16	23·69	23·97	24·57	23·14	—
Centre of eye to anterior end of ear aperture	5·04	5·20	4·73	5·20	4·88	4·52	4·73
Notch of flukes to posterior margin of anus	30·26	30·87	29·67	27·60	27·02	25·14	27·20
Notch of flukes to anterior margin of umbilicus	41·25	46·30	47·49	46·36	46·55	47·61	41·53
Length of pectoral fin, tip to anterior insertion	13·20	12·19	14·95	12·30	12·50	12·9	—
Length of pectoral fin, tip to posterior insertion	8·75	8·63	8·309	—	8·04	9·04	—
Median length of pectoral fin	11·57	10·69	10·86	11·20	11·06	12·27	—
Pectoral fin, greatest breadth	2·87	2·78	2·78	2·83	2·73	2·79	—
Dorsal fin, length	5·34	5·89	5·29	6·78	6·89	5·98	5·51
Dorsal fin, vertical height	2·22	2·05	2·08	2·83	2·73	2·92	1·84
Number of ventral furrows	75	61	65	—	64	64	65

Proportions.—Table XVI. *B. sibbaldii.* Table XVII. *B. borealis.* Table XVIII. *Megaptera longimana.*

Number of Whale	No. 17 ♀	No. 33 ♀	No. 34 ♀	No. 49 ♀	No. 46 ♀	No. 28 ♂
	Ft. in.	Ft. in.	Ft. in.	Ft. in.		Ft. in.
Total length	78 2	70 7	68 6	68 0	[illegible]	45 8
	%	%	%	%	%	%
Tip of snout to spiracle	15·82	17·36	18·11	19·17	16·46	15·5
Tip of snout to posterior insertion of pectoral fin	35·13	34·00	35·28	32·10	33·82	33·94
Tip of snout to posterior insertion of dorsal fin	85·45	77·91	[illegible]	74·73	70·46	67·51
Tip of snout to centre of eye	20·46	[illegible]	[illegible]	19·86	20·38	26·09
Symphysis of jaw to centre of eye	25·53	[illegible]	26·05	24·14	24·83	29·56
Centre of eye to anterior end of ear aperture	—	4·60	4·15	4·90	5·18	5·65
Notch of flukes to posterior margin of anus	28·16	27·83	28·52	28·56	26·12	23·91
Notch of flukes to anterior margin of umbilicus	45·04	46·05	45·13	46·57	47·07	40·69
Length of pectoral fin, tip to anterior insertion	13·93	17·12	17·79	19·17	14·31	31·38
Length of pectoral fin, tip to posterior insertion	9·59	11·10	11·68	11·27	10·02	23·42
Median length of pectoral fin	11·08	12·75	14·23	12·99	12·34	27·92
Pectoral fin, greatest breadth	3·79	3·54	4·01	3·94	2·68	7·30
Dorsal fin, length	3·90	3·36	4·25	3·92	6·08	10·22
Dorsal fin, vertical height	1·05	·88	·97	1·34	4·47	3·10
Number of ventral furrows	69	73	60	64	47	23

TABLE XIX.—*Physeter macrocephalus* (L.). Proportions.

Number of Whale	No. 15 ♂	No. 16 ♂	No. 21 ♂	No. 22 ♂	No. 25 ♂	No. 26 ♂
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	57 5	56 3	60 6	57 3	53 0	56 2
	%	%	%	%	%	%
Front of snout to posterior pectoral	41·80	42·96	41·74	39·74	41·03	43·41
Front of snout to posterior dorsal	69·64	69·77	68·89	66·80	69·44	—
Tip of upper jaw to angle of mouth	—	17·78	18·04	18·92	21·54	19·73
Tip of lower jaw to angle of mouth	17·85	17·34	17·22	18·63	22·17(?)	19·58
Notch of flukes to posterior margin of anus	—	26·34	29·34	28·23	23·58	27·29
Notch of flukes to anterior margin of umbilicus	—	46·[illegible]	45·45	47·01	33·32	—
Length of pectoral fin, tip to anterior insertion	9·14	9·03	7·68	8·00	7·54	8·45
Length of pectoral fin, tip to posterior insertion	6·96	5·77	5·78	3·93	3·14	3·11
Median length of pectoral fin	8·27	7·25	6·06	6·11	6·60	7·12
Pectoral fin, greatest breadth	4·78	4·44	4·71	4·51	4·55	4·45
Dorsal fin, length	7·54	8·89	7·30	10·91	6·74	10·68
Dorsal fin, vertical height	2·03	2·07	3·02	2·18	1·51	2·37
Length of head, dorsal	—	—	36·10	—	35·53	35·60
Height of head, at anterior end of mouth	17·42	—	18·04	—	15·25	16·46
Width of snout	9·14	—	8·67	—	8·64	9·34

Fœtuses.—Proportions.—TABLE XX. *B. musculus.* — TABLE XXI. *B. sibbaldii.*

No. of Parent	No. 19 ♂	No. 30 ♀	No. 35 ♀	No. 43 ♂	No. 47 ♂	No. 33 ♀
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Total length	15 0	—	7 10	3 11	9 4	7 7
	%	%	%	%	%	%
Tip of snout to spiracle	12·77	—	10·77	12·77	—	13·74
Tip of snout to posterior insertion of pectoral fin	23·83	—	30·32	32·14	—	37·07
Tip of snout to posterior insertion of dorsal fin	74·44	—	76·6	74·47	—	77·49
Tip of snout to centre of eye	17·77	—	18·35	17·82	—	18·68
Symphysis of jaw to centre of eye	20·55	—	21·01	20·74	—	20·88
Centre of eye to anterior end of ear aperture	—	—	5·85	6·91	—	6·86
Notch of flukes to posterior margin of anus	28·61	—	27·04	28·34	—	31·87
Notch of flukes to anterior margin of umbilicus	45·00	—	46·02	46·01	—	60·88
Length of pectoral fin, tip to anterior insertion	15·84	—	13·82	12·76	12·61	17·58
Length of pectoral fin, tip to posterior insertion	11·11	—	9·04	9·35	9·82	11·81
Median length of pectoral fin	12·50	—	10·64	10·64	11·61	14·02
Pectoral fin, greatest breadth	3·47	—	2·91	2·81	3·12	4·12
Dorsal fin, length	6·66	—	6·38	3·53	6·25	4·67
Dorsal fin, vertical height	2·77	—	3·45	2·12	3·12	1·09
Width of flukes	23·61	—	23·14	19·14	—	23·08
Number of ventral furrows	73	71	49	52 (faint)	—	83

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Mr. E. S. GOODRICH (*Chairman*), Dr. J. H. ASHWORTH (*Secretary*), Sir E. RAY LANKESTER, Professor W. C. MCINTOSH, Dr. S. F. HARMER, Professor S. J. HICKSON, Mr. G. P. BIDDER, Dr. W. B. HARDY, *and* Dr. A. D. WALLER.

THE British Association table at Naples has been occupied since the beginning of October 1913 by the Hon. Mary E. Palk, and from March 17 to April 15, 1914, by Mrs. H. L. M. Pixell-Goodrich. An application for the use of the table in September and October has been received from Mr. J. Mangan, M.A., Government School of Medicine, Cairo.

The following reports have been received:—

The Hon. Mary E. Palk reports: 'I have occupied the Naples table of the British Association since October last. I have been engaged on a revision of Professor Anton Dohrn's monograph of the Pycnogonida of the Bay of Naples. The work is slow because of the difficulty of preparing these animals, and the modifications I have made to Dr. Dohrn's work are chiefly histological. I have been unsuccessful in my attempts to study the habits of the living animal. I do not yet feel justified in publishing the results of my researches, as most of my conjectures require further proof, which it is not always easy to obtain.'

Mrs. H. L. M. Pixell-Goodrich reports: From March 17 to April 15, 1914, I occupied the British Association table at the Stazione Zoologica, Naples. During this time I searched for parasitic Protozoa in various marine invertebrates, and investigated chiefly stages in the development and sporogony of Lithocystis and Urospora of *Echinocardium cordatum* and Gonospora of *Glycera siphonostoma*. The results of these researches I hope shortly to publish.'

The Committee being wishful to encourage zoologists and physiologists to apply for the use of the table, and believing they are often deterred from applying by an exaggerated idea of the expense involved, prepared a statement giving an estimate of the cost of going to and living in Naples. A copy of this statement was sent to every zoological laboratory and most of the physiological laboratories in the United Kingdom. It is hoped that increased use will be made of the excellent facilities which the table offers for the prosecution of researches in Zoology and in the Physiology (including the chemistry) of marine organisms.

In the report for last year attention was drawn to the sum of 50*l.* remaining in the hands of the Committee. Professor Hickson, on retiring from the Chairmanship of the Committee, transferred this sum to the present Chairman. The Committee have therefore required only 50*l.* from the Association this year to complete the sum due for the upkeep of the table.

The Committee ask to be reappointed with a grant of 100*l.*

Marine Laboratory, Plymouth.—Report of the Committee, consisting of Professor A. DENDY (*Chairman and Secretary*), Sir E. RAY LANKESTER, Professor SYDNEY H. VINES, Mr. E. S. GOODRICH, *and* Professor J. P. HILL, *appointed to nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.*

SINCE the date of the last report the use of the table has been granted to Mr. J. S. Dunkerly for one month for the purpose of investigating Protozoa, especially those parasitic in fish.

Experiments in Inheritance.—Final Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Mr. R. DOUGLAS LAURIE (*Secretary*), Professor R. C. PUNNETT, *and* Dr. H. W. MARETT TIMS, *appointed to enable Mr. Laurie to conduct such Experiments.* (*Drawn up by the Secretary.*)

THE experiments were commenced in December 1907 with the object set forth in the first interim report presented to the Dublin Meeting of the Association in 1908. They were brought to an end in 1911, and some of the results summarised in the report to the Portsmouth Meeting that year. A more detailed account is now given in this final report.

The data concern in the main two matters: (A) the inheritance of yellow coat colour in mice, and (B) the inheritance of dense and dilute colourations in mice.

The following dense colours have come under my notice during the experiments: yellow, golden-agouti, cinnamon-agouti, black, and chocolate. On the presence and absence hypothesis,

homozygous	golden-agouti	may be represented	by zygotic	formula	yy GG BB Ch Ch.
,,	cinnamon-agouti	,,	,,	,,	yy GG bb Ch Ch.
,,	black	,,	,,	,,	yy gg BB Ch Ch.
,,	chocolate	,,	,,	,,	yy gg bb Ch Ch.

where Y = factor for yellow colour (not barred).
G = ,, ,, barred arrangement of yellow colour found in hairs of agouti (grey) mice.
B = ,, ,, black colour.
Ch = ,, ,, chocolate colour.

Yellow appears to be always heterozygous, and zygotic formulæ representing various kinds of yellow mice may be arrived at by replacing yy of the above series by Yy.

Each of the above colours may occur in a dense form, in which the pigment is densely deposited, or in a dilute form; these dense and

Yellow × Yellow	Yellow	Golden-agouti	Cinnamon-agouti	Black, *i.e.*, dense black	Chocolate, *i.e.*, dense chocolate	Total
42 ♂ (ex yel. × yel.) × 44 ♀ (ex yel. × yel.)	4	1	—	—	—	5
494 ♂ (,, ,, ,,) × 1054 ♀ (,, ,, ,,)	1	—	2	—	—	3
15 ♂ (,, ,, ,,) × 18 ♀ (,, ,, ,,)	1 (45 ♂)	—	—	3	—	4
15 ♂ (,, ,, ,,) × 43 ♀ (,, ,, ,,)	2	—	—	1	—	3
15 ♂ (,, ,, ,,) × 44 ♀ (,, ,, ,,)	4 {67 ♂, 68 ♀, 69 ♂}	—	—	1	—	5
7 ♂ (,, ,, ,,) × 13 ♀ (,, ,, ,,)	4	—	—	1	—	5
891 ♂ (,, ,, ,,) × 893 ♀ (,, ,, ,,)	3 {1053 ♀, 1054 ♀}	—	—	1	—	4
890 ♂ (,, ,, ,,) × 823 ♀ (,, ,, ,,)	—	—	—	2	2	4
159 ♂ (,, ,, ,,) × 160 ♀ (,, ,, ,,)	2 (494 ♂)	—	—	—	1	3
820 ♂ (,, ,, ,,) × 821 ♀ (,, ,, ,,)	3	—	—	—	6	9
1303 ♂ (,, ,, ,,) × 1289 ♀ (,, ,, ,,)	6	—	—	—	2	8
1222 ♂ (,, ,, ,,) × 1221 ♀ (,, ,, ,,)	4	—	—	—	—	4
1222 ♂ (,, ,, ,,) × 1221 ♀ (,, ,, ,,)	3	—	—	—	2	5
(1) 67 ♂ (,, ,, ,,) × 68 ♀ (,, ,, ,,)	1	—	—	—	—	1
(1) 67 ♂ (,, ,, ,,) × 68 ♀ (,, ,, ,,)	5	—	—	—	—	5
(2) 494 ♂ (,, ,, ,,) × 160 ♀ (,, ,, ,,)	3	—	—	—	—	3
(3) 15 ♂ (,, ,, ,,) × 19* ♀ (,, ,, ,,)	2 (49 ♂)	—	—	—	—	2
506 ♂ (ex choc. ,,) × 823 ♀ (,, ,, ,,)	1	—	—	—	3	4
(4) 79 ♂ (ex blue ,,) × 1054 ♀ (,, ,, ,,)	3 (1303 ♂)	—	—	—	—	3

(4) (5)	79 ♂ (ex blue × yel.) × 1053 ♀ (ex yel. × yel.)	2 (1289 ♀)	—	—	—	—	2
	1349* ♂ (ex yel. × yel.) × 1183 ♀ (ex black × yel.)	3	—	—	—	—	3
	1040 ♂ (ex sil.-fawn ,,) × 1092 ♀ (ex blue × yel.)	2	—	—	1	—	3
	235 ♂ (ex choc. ,,) × 1184 ♀ (,, ,, ,,)	—	—	—	1	2	3
	1025 ♂ (ex sil.-fawn ,,) × 1101 ♀ (ex sil.-fawn × yel.)	—	—	—	2	1	3
	1025 ♂ (,, ,, ,,) × 1026 ♀ (,, ,, × ,,)	1	—	—	—	1	2
	83 ♂ (ex choc. ,,) × 87 ♀ (ex choc. × yel.)	2	—	—	—	1	3
	522 ♂ (,, ,, ,,) × 521 ♀ (,, ,, ,,)	2	—	—	—	2	4
	522 ♂ (,, ,, ,,) × 521 ♀ (,, ,, ,,)	2	—	—	—	—	2
	473 ♂ (ex sil.-fawn × yel.) × 474 ♀ (ex sil.-fawn × yel.)	2	—	—	—	1	3
	235 ♂ (ex choc. × yel.) × 1183 ♀ (ex black × yel.)	2 (1349 ♂)	—	—	—	—	2
	83 ♂ (,, ,, ,,) × 85 ♀ (ex choc. × yel.)	2	—	—	—	1	3
	Observed . . .	72	1	2	13	25	113
			$\underbrace{\qquad\qquad\qquad\qquad}_{41}$				
	Calculated 2 : 1 = 75·3		37·6				
	Calculated 3 : 1 = 84·75		28·25				

7 ♂, 13 ♀, 15 ♂, 18 ♀, 19 ♀ were obtained from reliable dealers and I was able to see their actual parents.

(1) 67 ♂ yel. × choc. gave yellow, black and chocolate.
68 ♀ yel. × sil.-fawn gave yellow and chocolate.

(2) 494 ♂ yel. × sil.-fawn gave yellow and cinnamon-agouti.
160 ♀ yel. × yel. gave yellow and chocolate.

(3) 15 ♀ yel. × choc. gave yellow and black.

(4) 79 ♂ yel. × sil.-fawn gave yellow, black and chocolate.
1054 ♀ yel. × sil.-fawn gave yellow and black.

(5) 1053 ♀ yel. × sil.-fawn gave yellow and black.

* See text discussion of matings, under (a).

dilute conditions are allelomorphic, and may be represented by presence or absence of the factor D.

Further, any of the above conditions may be present potentially, but remain undeveloped in absence of some colour-activating material *which may be represented by factor C; in the* absence of this factor the animal is an albino.

A. The Inheritance of Yellow Coat Colour in Mice.

In the first place, all my yellow mice appear to be heterozygous in respect of their yellow coat colour; none which have been fairly tested breeding true to yellowness, but on the other hand giving offspring which include, in addition to yellows, a proportion of individuals whose colour is other than yellow. Yellow is incompletely epistatic to black and chocolate. I find that, as Durham points out, black pigment may be present in the hairs of yellows throwing blacks, and chocolate pigment in the hairs of yellows throwing chocolates. Moreover, the degree of development of these other pigments in the hairs varies a good deal during the life of the animal.

The tendency to abnormal fattening of yellow mice pointed out by Durham was also evident in the mice used by me.

I arrange the matings which concern yellow mice in two tables: yellow × yellow, and yellow × other colour. The abbreviations in brackets indicate the immediate parentage of the mice concerned. Where the heterozygous nature of a yellow mouse is not shown in the table by its offspring a note is added of some additional mating showing it to be heterozygous (see tables on pp. 164, 165, and 168, 169).

I. In regard to the matings yellow × yellow given in the table on pp. 164 and 165 certain points may be noted:

(*a*) Twenty-six of the mice used were derived from the cross yellow × yellow, and expectation was that at least one-third of these would prove to be true-breeding yellows. There are only two, however (marked with asterisk), which could possibly answer to this condition, and there is no evidence about them beyond that given in the table. It will be seen that they produced only two and three young respectively. Matings with other mice designed to test them gametically proved sterile. It would evidently be inappropriate to quote these as examples of mice homozygous in yellow.

(*b*) The total number of offspring is 72 yellow and 41 other colour. On the theory that yellow-bearing gametes do not conjugate, one would expect the ratio 3 : 1, from which the calculated result of the above matings would be 84·75 : 28·25, a very poor approximation indeed. On the alternative theory that the yellow-bearing gametes do actually conjugate but that the zygotes so produced perish before birth, one would expect the ratio 2 : 1, from which the calculated result would be 75·3 : 37·6, a very close approximation to the experimental figures. The latter suggestion, moreover, harmonises with the

combined results of Cuénot, Castle, and Durham. Adding my own results to those of the other observers named, we find:—

	Yellow.	Other colour.
Cuénot	263	100
Castle (1910)	800	435
Durham (1911)	448	232
Laurie	72	41
Experimental	1583	808
Calculated 2 :*1	1594	797

It is of interest to find this anomalous result confirmed from experiments with an additional independent strain of mice.

(c) The number of young in a litter from yellow × yellow which survive to an age at which their colour is determinable is small, averaging only 3·64, as against 4·58 among mice of other colours. It is possible that this is associated with the hypothetical abortion of zygotes homozygous in yellow. Cuénot and Castle find a similar though smaller difference in size of family; but, on the other hand, Durham does not. (See Appendix A.).

II. The table on pp. 168 and 169 shows a list of matings of yellow × other colour. One notes:

(a) The 54 matings of yellow × other colour give 131 yellow: 125 other coloured young, expectation being, on the supposition that all the yellows were heterozygous, 128 : 128.

(b) There were 36 yellow mice involved in the matings, of which 11 were known from their parentage to be heterozygous. The remaining 25 were derived from yellow × yellow, and one-third at least of these should have been gametically pure to yellow and have given only yellow young when mated to mice of any other colour. But all save one, and this had a couple of youngsters only, threw some other colour in addition to yellow.

(c) Of the 25 yellow mice ex yellow × yellow 14 are recorded also in the list of matings of yellow × yellow, so that 11 remain to be added to the 26 of the other list, making 37 yellow mice of which both parents were yellow, and of which none, on being tested adequately, proved to be homozygous, though about a dozen should have been so, even assuming both the yellow parents to have been in each case heterozygous.

(d) The number of young in a litter from yellow × other colour which survived to an age at which their colour was determinable averages 4·74, much the same as in the case of matings in which both parents are some colour other than yellow, where the average is 4·58. There is no reason associated with the theory of abortion of zygotes Y Y why this should be otherwise. There is, of course, no opportunity for the formation of such zygotes in the mating of yellow × other colour.

Black carrying blue (Dd BB) × silver-fawn (dd bb).

F_1	1 black :	4 blue	observed.
	2·5	2·5	calculated 1 . 1 ratio.

Black carrying chocolate (DD Bb) × silver-fawn (dd bb).

F_1	14 black :	10 chocolate	observed.
	12	12	calculated 1 . 1 ratio.

Black carrying blue (Dd BB) × black carrying silver-fawn (Dd Bb).

F_1	2 black :	1 blue	observed.
	2·25	0·75	calculated 3 . 1 ratio.

Black carrying blue (Dd BB) × black carrying chocolate (DD Bb).

F_1	4 blacks	observed.
	4	calculated.

Black × chocolate.

Black homozygous (DD BB) × chocolate homozygous (DD bb).
F_1 black (DD Bb).

F_2	16 black :	7 chocolate	
	42	17	Durham.
	58	24	observed.
	61·5	20·5	calculated 3·1 ratio.

Black homozygous (DD BB) × black carrying chocolate (DD Bb).
F_1 black. Four matings gave 16 black young.

Black carrying chocolate (DD Bb) × chocolate homozygous (DD bb).

F_1	4 black :	4 chocolate	observed.
	4	4	calculated 1 . 1 ratio.

Black × blue.

No matings DD BB × dd BB, but F_1 from black (DD BB) × black carrying blue (Dd BB) gave 16 black young as the result of three matings.

F_2. None of the F_1 generation were mated, but the following results of matings between blacks unconnected with the above are such as would be expected if both blacks carried blue (Dd BB).

Dd BB		Dd BB				
33 ♂	×	35 ♀	gave	5 black :	2 blue.	
33 ♂	×	35 ♀	,,	3	1	
33 ♂	×	36 ♀	,,	7	2	
26 ♂	×	23 ♀	,,	1	1	
				16	6	
				50	13	Durham, F_2 from black × blue.
				66	19	observed.
				63·75	21·25	calculated 3 . 1 ratio.

Chocolate × silver-fawn.

Chocolate homozygous (DD bb) × silver-fawn (dd bb).
F_1 chocolate (Dd bb).

F_2	14 chocolate :	7 silver-fawn.	
	3	1	ex pair chocs. of unknown parentage.
	17	8	observed.
	18·75	6·25	calculated 3 . 1 ratio.

Durham did not carry any mating of the above type into the F_2 generation.

Chocolate carrying silver-fawn (Dd bb) × silver-fawn (dd bb).

F_1	7 chocolate :	10 silver-fawn	observed.
	8·5	8·5	calculated 1 . 1 ratio.

Blue × silver-fawn.

No matings dd BB × dd bb. But, as above recorded, a black carrying blue (Dd BB) × silver-fawn (dd bb) gave black and blue in F_1.

F_2 from these F_1 blues (dd Bb):

2 blues :	2 silver-fawns.	
4	1	ex pair blues of unknown parentage.
6	3	
46	17	Durham.
52	20	observed.
54	18	calculated 3 . 1 ratio.

Silver-fawn × silver-fawn.

Silver-fawns should breed true, since they represent the lowest term of the epistatic colour series associated with absence of factor for dense deposition of pigment. Zygotic formula dd bb.

Five matings between silver-fawns gave 28 silver-fawn young.

APPENDIX A.

Average Number of Young in Litter.

Durham's data are included for comparison; each of her averages is based on at least 75 litters.

		Average per litter Laurie	Durham
Yellow	× yellow	3·64 (31 litters)	3·90
Yellow	× other colour	4·74 (54 „)	3·97
Agouti	× agouti		3·47
Agouti	× other colour (not yellow)		3·32
Black	× black	4·83 (23 „)	4·60
Black	× other colour (not yellow)	4·29 (14)	3·99
Blue	× blue	4·24 (21)	
Blue	× other colour (not yellow)	5·12 (26)	
Chocolate	× chocolate	4·32 (25)	3·96
Chocolate	× other colour (not yellow)	4·71 (34)	3·93
Silver-fawn	× silver-fawn	5·60 (5)	
Silver-fawn	× other colour (not yellow)	4·79 (14)	
Albino	× albino	5·18 (17)	
Albino	× yellow	4·60 (25)	
Albino	× colour (not yellow)	4·19 (41 „)	4·27

In the above records, both Miss Durham's and my own, only those mice are counted which lived long enough for their colours to be determined.

The strikingly smaller size in my experiments of the average litter ex yellow × yellow, as compared with the other matings, is commented on above. A lesser difference was observed by Cuénot also (yellow × yellow 3·38; yellow × other colour 3·74) and Castle (yellow × yellow 4·71; yellow × other colour 5·57). On the other hand, Durham's figures warn one to be cautious as to one's inferences.

The data from which the above averages are calculated are as follows:—

Yellow × yellow. See list.
Yellow × other colour. See list.
Black × black gave 7, 5, 3, 6, 7, 9, 4, 2, 8, 4, 2, 5, 4, 4, 4, 3, 2, 6, 5, 7, 7, 3, 4.
Black × blue gave 3.
Black × chocolate gave 2, 2, 4, 2.
Black × silver-fawn gave 5, 6, 6, 8, 4, 6, 2, 5, 5.
Blue × blue gave 7, 4, 4, 7, 2, 4, 3, 6, 3, 2, 3, 5, 4, 6, 5, 4, 3, 8, 2, 2, 5.
Blue × chocolate gave 5, 7, 5, 2, 7, 5, 6, 5, 4, 4, 7, 8, 7, 4, 3, 5, 2, 4, 6, 7, 4, 7, 3, 6, 7.
Blue × black. See black × blue.
Chocolate × chocolate 7, 4, 5, 3, 5. 3, 1, 2, 2, 2, 5, 6, 6, 5, 6, 2, 2, 5, 6, 6, 4, 6, 7, 3, 5.
Chocolate × silver-fawn gave 5, 3, 1, 7, 4.
Chocolate × blue. See blue × chocolate.
Chocolate × black. See black × chocolate.
Silver-fawn × silver-fawn gave 7, 3, 6, 6, 6.
Silver-fawn × black. See black × silver-fawn.
Silver-fawn × chocolate. See chocolate × silver-fawn.
Albino × albino gave 5, 2, 4, 6, 6, 5, 6, 4, 5, 6, 5, 4, 6, 7, 6, 5, 6.
Albino × yellow gave 6, 1, 4, 5, 6, 6, 4, 5, 7, 6, 7, 5, 5, 3, 3, 5, 5, 5, 4, 2, 7, 3, 7, 2, 2.
Albino × colour other than yellow gave 4, 3, 4, 1. 7, 2, 4, 7, 5, 8, 6, 5, 6, 4, 4, 7, 5, 6, 3, 3, 2, 4, 1, 2, 2, 2, 4, 8, 4, 2, 5, 6, 3, 4, 5, 5, 6, 2, 5, 4, 2.

APPENDIX B.

Albino Mice.

I crossed many of my mice with albinos in the process of testing their genetic behaviour. There appears to be no need to set out the results in detail, but the following points may be noted:—

The size of litter in the three types of mating—albino × albino, albino × yellow, and albino × colour other than yellow—is given in Appendix A.

The colour composition of the litters from albino × colour conformed to the rules now well established for the heredity of albinism in mice.

Fourteen of the matings albino × colour yielded some albino young: the total young from these matings numbered 37 albino: 30 coloured, expectation being equality.

APPENDIX C.

Piebald Mice.

A piebald chocolate-and-white mouse appeared in a litter born to a chocolate mouse bought in kindle from a dealer. I bred from it to the F_2 generation in order to assure myself that it acted as a recessive to self-colour.

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The Question of Fatigue from the Economic Standpoint.—Interim Report of the Committee, consisting of Professor J. H. MUIRHEAD (*Chairman*), Miss B. L. HUTCHINS (*Secretary*), Miss A. M. ANDERSON, Professor BAINBRIDGE, Mr. E. CADBURY, Mr. P. SARGANT FLORENCE, Professor STANLEY KENT, Mr. W. T. LAYTON, Dr. T. G. MAITLAND, Miss M. C. MATHESON, Dr. C. S. MYERS, Mr. J. W. RAMSBOTTOM, *and* Dr. J. JENKINS ROBB. *In addition, help has been kindly afforded by the following:* Miss MABEL ATKINSON, Dr. WM. BROWN, Mr. ARTHUR GREENWOOD, *and* Dr. UDNEY YULE.

THE Committee has met four times, and has made a preliminary survey of the subject of investigation, and has discussed the matter at some length.

An extensive Bibliography of Fatigue has been prepared for the use of the Committee by Miss B. L. Hutchins.

A short report has been drawn up on industrial experiments in shortening hours, also by Miss Hutchins.

Some notes have been kindly contributed by Dr. William Brown on the existing state of psychological knowledge in regard to fatigue.

A Memorandum on the provisional aims and methods of the inquiry has been drawn up by Mr. Ramsbottom, and adopted by the Committee as a basis of its future work.

As a result of our preliminary survey, we have become aware that a considerable amount of work on the subject has been done in America and on the Continent of Europe, and, so far, comparatively little in this country.

We consider, however, that but little definite information exists, and detailed scientific investigation is badly needed, especially in view of the rapid development of the factory industry and the progressive urbanisation of the working class in this country.

We propose, if reappointed, to adopt the following method of investigation:—

Mr. Ramsbottom has defined the object of inquiry as being 'to

ascertain the effect on physique, accident occurrence, production and general social well-being of present conditions relating to fatigue occurrence in industrial work, and to discuss possible improvements therein, and the best methods of obtaining them.' We concur with this definition.

We hope that Dr. Maitland, being a member of our Committee, will prepare a short résumé of existing knowledge on the effects of muscular and mental fatigue respectively. We shall also endeavour to ascertain what are the main subjective and objective determinants of fatigue; *e.g.*, what is the relative importance of muscular work, mental strain, monotony, atmospheric wet-bulb temperature (kata-thermometric condition), noise, light, etc.; and to discover some reliable physiological quantitative index of fatigue, and the chief physiological effects of over-fatigue.

We shall consider the questions what increase, if any, has occurred in general morbidity in recent years, and to what extent this can be ascribed to industrial fatigue; and what difference can be traced between the morbidity cases of workers in various age groups from fifteen upwards engaged in occupations involving long hours of work or specially fatiguing conditions, and those for all workers or workers in fairly easy occupations.

We shall also consider the incidence of industrial accidents in relation to hours of work; and the variation in the output of work per hour during the day, and the output per day with various lengths of working-day.

We propose to give special attention to the speeding-up of machinery, and to inquire how far this has been accompanied by a reduction of hours.

We shall also consider the probable social reactions of over-fatigue, and what general remedies, if any, may seem most promising and hopeful.

The Committee has made a preliminary division of the work, as so sketched, among the following sub-committees:—

Physiological and Psychological.	*Industrial.*	*Statistical.*
Dr. Maitland (*Convener*).	Miss Anderson.	Mr. Layton (*Convener*).
Prof. Muirhead.	Mr. Cadbury.	Miss Hutchins.
Dr. Myers.	Mr. Florence (*Convener*).	Mr. Ramsbottom.
Dr. Bainbridge.	Miss Hutchins.	Dr. Yule.
Dr. Legge.	Miss Matheson.	
	Mr. Ramsbottom.	

And we have appointed Mr. Ramsbottom as hon. organising secretary.

For purposes of the foregoing inquiries we think it will be essential to obtain the services of expert and paid assistants.

The Committee ask to be reappointed, with the addition of the words 'social and' before 'economic,' in their terms of reference, and to be allotted a grant.

Gaseous Explosions.—Seventh Report of the Committee, consisting of Dr. DUGALD CLERK *(Chairman)*, Professor DALBY *(Secretary), and* Professors W. A. BONE, F. W. BURSTALL, H. L. CALLENDAR, E. G. COKER, H. B. DIXON, Drs. R. T. GLAZEBROOK *and* J. A. HARKER, Colonel H. C. L. HOLDEN, Professors B. HOPKINSON *and* J. E. PETAVEL, Captain H. RIALL SANKEY, Professors A. SMITHELLS *and* W. WATSON, Mr. D. L. CHAPMAN *and* Mr. H. E. WIMPERIS.

THE decease of the Chairman, Sir William Preece, was reported to the Committee in December last, when a letter of condolence was sent to the family.

Sir William Preece had associated himself intimately with the investigations carried out by the Committee, and contributed an interesting Note on the Kinetic Theory of Gases. As Chairman he did much to help forward the important work on which the Committee is engaged both by his valuable suggestions and by his tactfulness and resource. His loss is not only deeply deplored, but felt to be a personal one by every member of the Committee.

The Vice-Chairman, Dr. DUGALD CLERK, was unanimously elected Chairman.

The Committee met three times during the session 1913-14 at the City and Guilds (Engineering) College, Exhibition Road, London, S.W. The following Notes were presented and discussed:—

Note 32 by Professor DALBY on Suction Temperatures directly measured and deductions therefrom, together with a summary of a series of seventeen experiments made at the City and Guilds (Engineering) College on a Crossley gas-engine with a cylinder seven inches in diameter, stroke fourteen inches, and with a compression ratio at 4·8.

Note 33 by Mr. H. E. WIMPERIS on Thermal Efficiency.

Note 34 by Professor E. G. COKER and Mr. W. A. SCOBLE on Temperature Distribution in the Cylinder of a Gas-engine.

Note 35 by Professor W. WATSON on the Spectroscopic Study of the Combustion of Air-petrol Mixtures.

The object of Note 32 was to show how the suction temperature varied with the speed, with the jacket temperature, and with the mixture. The records given in the Note relate to trials Nos. 72 to 90. The data were obtained by a research student of the City and Guilds (Engineering) College, Mr. Limbourne, working under the supervision of Professor Dalby. A table included in the Note shows the variation in the suction temperatures, and a set of curves, also included, gives the temperatures of the working mixture; these indicate how the direct knowledge of the suction temperature can be applied to determine the temperatures at other parts of the cycle.

In Note 33 Mr. Wimperis discusses the thermal efficiency of an engine using as the working agent a standard gas referred to in the first

report of the Committee, and using in his calculations the values of the internal energy defined by the curve in fig. 6 of that report.

In Note 34 Professor Coker describes the method of measuring the cyclical temperature in a gas-engine cylinder used by him at the Technical College, Finsbury, and gives the results of some recent experiments. Curves are included showing the temperature of the explosive charge, together with tables of the actual temperatures at various points in the cycle. A full description of the thermo-couple used in these experiments is given in the Note.

In connexion with Note 35 Professor Watson showed a series of photographs of the spectrum of the light given by the burning charge in the cylinder of a petrol engine. The results show that the gases in the cylinder continue to emit light giving a line spectrum for a considerable time after the chemical changes are generally assumed to have been completed.

Before proceeding to consider the work carried out during the current session it has been thought advisable to give a brief summary of the previous reports of the Committee.

Summary of Previous Reports.

The first report is devoted mainly to the subject of the specific heats of gases at high temperatures. The constant-pressure experiments of Wiedemann, Regnault, Holborn, and Henning are analysed and discussed, and a curve is given showing the energy of CO_2, steam, and air in terms of the temperature Centigrade. The experiments of Dr. Dugald Clerk are described, and the results obtained compared with the constant-pressure experiments mentioned above. The closed vessel experiments of Mallard, Le Chatelier, and Langen are analysed and the results plotted and discussed.

The report ends with the discussion of thermal equilibrium, chemical equilibrium, the motion of a gas, and the measurement of temperature. A curve is given showing the internal energy of a gas-engine mixture in terms of the temperature.

There is an appendix by Professor Callendar on 'The Deviation of Actual Gases from the Ideal State,' and on 'Experimental Errors in the Determination of their Specific Heats.'

The second report is mainly devoted to the subject of the specific heat of gases at high temperatures. Regnault's results at low temperatures are discussed in the light of Mr. Swann's experiments, which were communicated to the Committee by Professor Callendar. The Committee definitely adopted Mr. Swann's values for air and for CO_2 as given below.

Volumetric heat of air at 100° C. is 19·8 lbs. per cubic foot,
„ „ CO_2 at 20° C. is 27·4 lbs. per cubic foot, and
at 100° C. is 30·7 lbs. per cubic foot.

The results of the experiments made by Dr. Dugald Clerk with the object of determining the volumetric heat of air at high temperature are given in the report, together with a description of Professor

Hopkinson's experiments on the compression of air in a gas-engine cylinder.

Dr. Watson's researches on the efficiency of a petrol motor are included in the report. Dr. Watson made a simultaneous measurement of the quantities of air and petrol taken into the engine and of the chemical composition of the exhaust gas. The point brought out was that the ratio of hydrogen to carbon in the exhaust gas was greater than the ratio of hydrogen to carbon in the petrol used. Additional evidence of this discrepancy is furnished by some experiments of Professor Hopkinson, and the experiments of Hopkinson and Watson are in agreement.

The report concludes with an account of the experiments on radiation carried out by Professor Hopkinson.

There are two appendices: one relating to Regnault's corrections in connection with the determination of the specific heat of air, and the other relating to Deville's experiments on the dissociation of gases by Dr. Harker.

The third report is devoted mainly to the consideration of the subject of radiation from gases. A brief general history of the subject is given, together with a record of the experiments of Professor Hopkinson and of Professor Callendar. The report discusses the direct effect of radiation on the efficiency of internal-combustion motors, the amount of radiation from flames, and the molecular theory of radiation from gases as well as the question of the transparency of flames to their own radiation. There is an appendix on the radiation of flames by Professor Callendar, giving some account of experiments made with a Mêker burner; a second appendix on the radiation in a gaseous explosion by Professor Hopkinson; and a third appendix which contains abstracts from various papers relating to the application of heat radiation from luminous flames to Siemens' Regenerating Furnaces.

The fourth report merely notes the number of meetings held during the year, and states that, partly owing to the breakdown of apparatus and partly to the demands made upon the time of the various investigators, only two notes were read; consequently it was decided that the work then on hand should be included in the report for the following year.

The fifth report continues the discussion of the effect of radiation, and is devoted mainly to the consideration of the factors which determine the heat flow from the gas to the walls of the cylinder. The remarkable effect of turbulence on the rate of combustion is first mentioned in this report. Particulars of Dr. Dugald Clerk's experiments are given, and these experiments definitely establish the fact that but for turbulence the speed at which modern internal-combustion engines are run would be impossible. Professor Hopkinson's experiments, in which a fan was placed inside a closed vessel and the rates of combustion observed with the fan at rest and in motion, are recorded in the report, and confirm Dr. Clerk's results.

In the sixth report the resignation of Dr. Dugald Clerk and Professor Hopkinson from the Joint Secretaryship of the Committee is

reported. Dr. Clerk consented, however, to act as Vice-Chairman, and Professor Dalby was appointed Secretary.

The Committee allocated the whole of the grant to the Secretary for the purpose of providing him with a permanent research assistant to carry on the work. It was stated that Professor Dalby and Dr. Clerk were engaged on the design of an experimental plant to be placed in the new laboratory of the City and Guilds (Engineering) College.

Six notes, relating chiefly to heat flow, temperature, and leakage, are briefly summarised.

Object of Present Report.

The following report is devoted partly to the special consideration of temperature measurements and subjects arising therefrom, and partly to the illustration of the use which can be made of the data obtained by the Committee.

Methods of Measuring Temperature of the Charge in a Gas-engine Cylinder under working conditions.

One of the problems requiring solution was the direct measurement of the temperature of the working agent in the cylinder while the engine was running under ordinary working conditions. The difficulty of making this measurement arises from the fact that during the

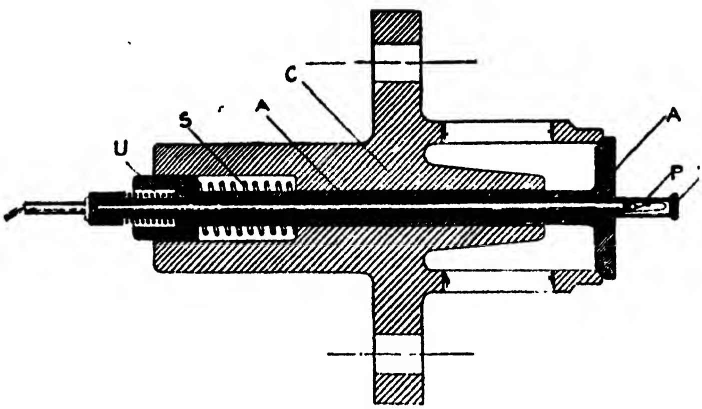

FIG. 1.

explosion of the charge in the engine cylinder the temperature is sometimes higher than that of the melting-point of platinum or of the couples which can be put in the cylinder to make the measurement.

In Note 32 is described a method devised by Professors Callendar and Dalby,[1] which for the first time enabled direct observation of the

[1] *Proc. Roy. Soc.*, A., vol. 80, 1907.

suction temperature to be made while the engine was working not only under normal conditions but under special conditions, during which the richest possible mixture was used and the temperature reached at explosion was considerably higher than that occurring in practice. The thermometer itself consisted of a piece of platinum wire about 0·7 inch long and $\frac{1}{1000}$ of an inch in diameter, arranged with compensating leads. It is placed in a thermometer-valve, which is inserted through the spindle of the admission-valve in the manner shown in fig. 1, in which P is the platinum thermometer, and T is the head of the thermometer-valve, which is inserted centrally in the

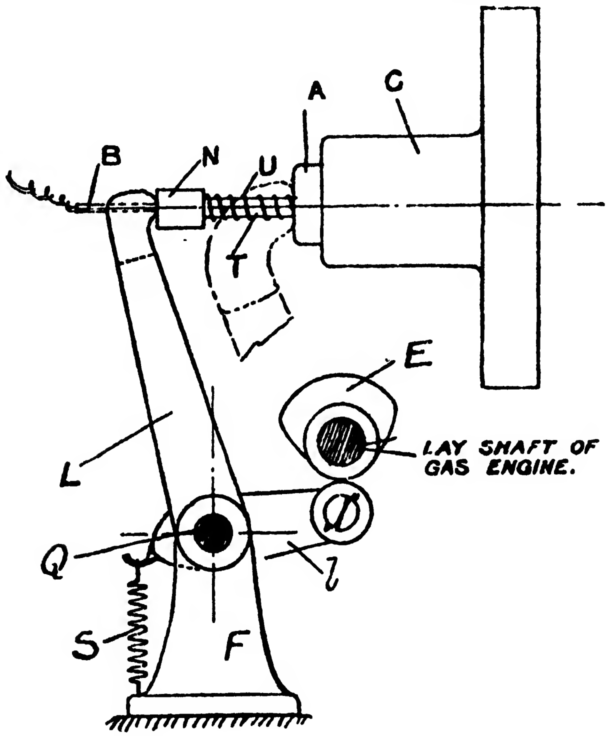

Fig. 2.

admission-valve A. The spring S serves to close the admission-valve, and the spring U serves to close the thermometer-valve. The main casting, C, carrying these valves is bolted to the engine in the ordinary way. A separate cam is mounted on the half-time shaft to operate the central thermometer-valve, and the complete arrangement is shown in fig. 2, where E is the cam; l and L are levers keyed to the supplementary shaft Q, which is carried on the casting F; the spring S maintains contact between the end of the lever l and the cam. The end of the thermometer with the leads projecting is shown at B. The lever L is in contact with the nut N on the thermometer-valve. The cam is so designed that during the explosion period the valve

is closed, and the thermometer therefore screened from the action of the gas. In this way the thermometer is withdrawn just before the end of compression, so that at this critical period of the cycle there is nothing in the shape of a protuberance to cause preignition. When the platinum thermometer is exposed in the cylinder and connected to the Wheatstone bridge and galvanometer on which the indications are received, the circuit is made by a contact-maker on the crank-shaft when the crank passes through an assigned crank-angle, and is broken by the contact-maker when the crank passes through a second assigned crank-angle a little greater than the first, so that the electrical

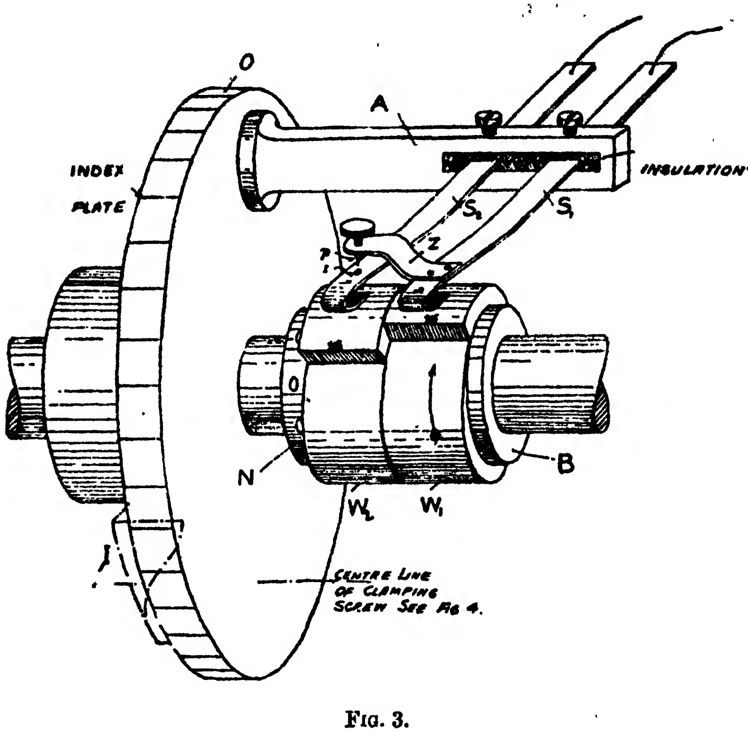

FIG. 3.

measuring device is in operation during 5°, 10°, or 15° as the case may be.

This contact-maker is a very important part of the electrical equipment used in connexion with these temperature measurements, as it enables a definite make and a definite break to be made in the electrical circuit, and, in addition, enables the time between the make and break to be adjusted with accuracy.

The contact-maker (fig. 3) consists of a brass bush B, keyed to a lay shaft of the engine, and carrying two fibre washers or cams W_1 and W_2, which can be clamped in any relative angular position against the flange of the bush by the nut N. A radial step, as u_1, is made in each washer, and the surface gradually rises from the bottom of the step to the normal circular surface of the washer. The reflexed ends

of the stiff springs S_1 and S_2 rest on the fibre cams. A projection Z carrying a platinum-pointed screw p is riveted to one of the springs, and the screw p is adjusted so that its point is just clear of the platinum rivet in the other spring when both springs are riding on the circular surfaces of their respective cams. Contact is made when the rotation of the lay shaft in the direction of the arrow brings the radial step w_1 of the cam W_1 under the spring S_1, thereby allowing it to fall down the step, thus bringing p and r together. Contact is broken when the radial step w_2 of the cam W_2 reaches the spring S_2, thereby allowing the second spring to fall down the step w_2. The epoch and duration of contact are readily adjusted by adjusting the angular positions of the cams relatively to the bush and also with regard to one another. The distances between the springs and the platinum contacts and the steps w are exaggerated in the diagram in order to make the principle of the apparatus clear. The percussion form of contact with platinum points is found to give definite and certain results The contacts keep

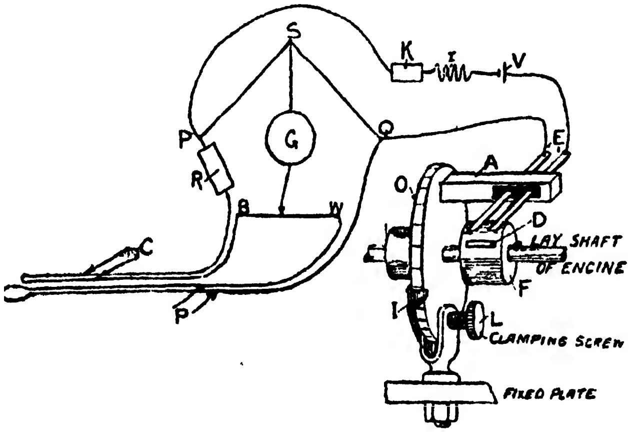

FIG. 4.

clean, and no trouble of any kind is experienced with them. The general arrangement of the electrical connections are shown in fig. 4. In this figure PS, QS are the equal ratio arms of the Wheatstone bridge. The galvanometer G is connected to the point S and to the sliding contact on the bridge-wire BW. The thermometer and its leads P are connected on one side of the bridge-wire, and the compensator C and the balancing resistance R on the other. The battery circuit includes a mercury reversing key K, an adjustable resistance r, and a storage cell V; and the battery is connected to the bridge at the points P and Q, and to the brushes of the periodic contact-maker at E. The brushes E are carried by an insulated arm A bolted to a divided disc O riding loosely on the lay shaft of the engine, and capable of being clamped in any position by the screw L. The index I shows the crank-angle corresponding to the middle point of the contact when the insulated copper strip D carried in the fibre bush F passes under the brushes.

The temperature is measured, therefore, during a particular crank-angle determined by the setting of the contact-maker. This can be set, while the engine is running, to determine the make and break at any assigned crank-angle in the revolution. It was usually set so that the interval between the make and break was 5° or 10°. In this manner the mean temperature over a small crank-angle can be measured at any point in the cycle, except only during the period of the explosions when the thermometer is withdrawn from the cylinder. But although there is this possibility with the method it is desirable to measure the temperature at a point on the cycle where the rate of change of temperature is at a minimum. This point occurs just after the closing of the suction-valve. The great advantage of making the measurement at this point is that the thermometer is exposed to the incoming charge during the whole of the suction-stroke and therefore the thermometer-valve tends to assume the temperature of the charge; consequently the temperature which the small wire is set to measure does not differ greatly from the temperature of the metal in which it is mounted. This condition tends to minimise the errors of measurement. At any other point in the cycle the rate of change of temperature is greater; and the error of the measurements, therefore, is likely to be greater owing to the lag of the thermometer. On the expansion-stroke, for example, the temperature may vary as *much as 150° during the movement of the piston through* $\frac{1}{10}$ *of the stroke. Just after the closing of the suction-valve* the variation of temperature during the movement of the piston through $\frac{1}{10}$ of the stroke is only about 20°.

Having found the temperature at one point in the cycle, the temperature at any other point can be calculated by using the charge itself as the thermometric agent. The characteristic equation of the charge is $\frac{PV}{T}$ = a constant. If, therefore, from the indicator diagram taken at the time the temperature was measured, the corresponding pressure and volume are measured, then the temperature at any other point of the cycle can be calculated by the aid of this constant and the pressure and volume scaled from the indicator diagram, allowance being made for chemical contraction of the charge after explosion. It is necessary to have accurate indicator diagrams from which to measure the pressure and volume for this purpose, and this has led to the development of an optical indicator.

Example of the Application of the Method to an Engine Trial (72) at the City and Guilds (Engineering) College.

The general procedure in making temperature measurements by this method, and with an improved optical indicator devised by Professor Dalby and Dr. Watson, may be illustrated by data obtained during a trial made at the City and Guilds (Engineering) College by Professor Dalby last year, a full report of which will be found in Note 32 communicated to the Committee.

Indicator Diagrams.

In each trial two indicator diagrams were taken—namely, a complete diagram showing the pressure and volume during the whole cycle, and a diagram taken with a thin disc stopped down so as to give on a large scale the portion of the diagram during the pumping-stroke. The diagrams are in general calibrated *in situ*.

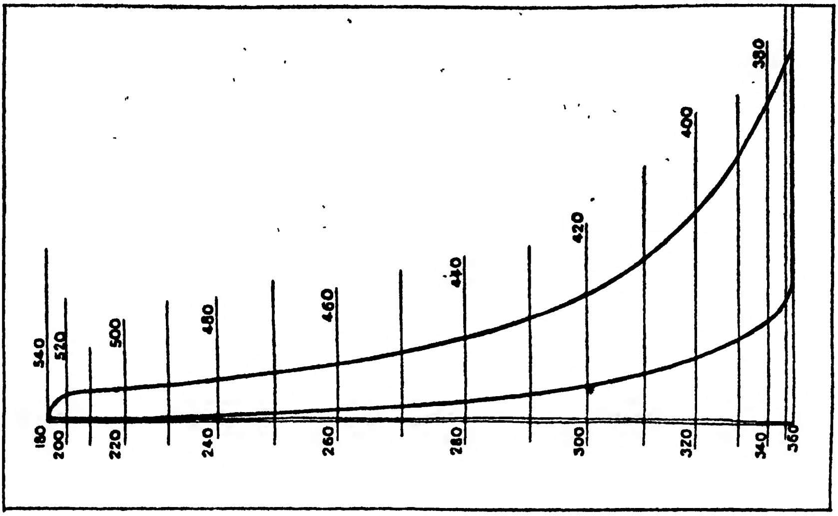

FIG. 5.

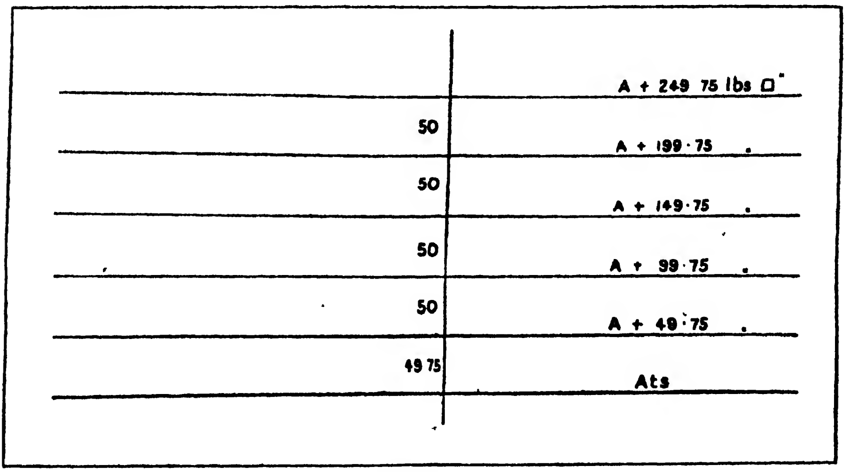

FIG. 6.

In carrying out a series of experiments, however, it was found that the scale was so constant that it was unnecessary to calibrate each diagram separately. The scale was therefore made for the two discs used, and was checked from time to time. A pair of typical diagrams

wire, BW, can be adjusted to 1 millivolt. This is tested by the electromotive force of a cadmium cell, C, which can be opposed to the battery electromotive force by means of the upper key, K_1, an allowance for the known temperature variation of the electromotive force of the standard cell used being made by an adjustable contact-maker, D. The thermo-electric couple, H, has one lead connected to the lower key, K_2, and the other set to a set of resistances, S, in the main circuit, each of which gives a difference of potential of 1 millivolt when the

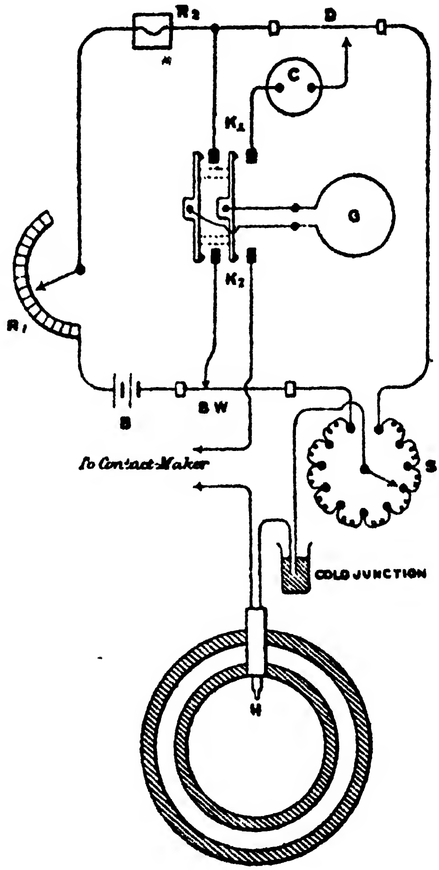

FIG. 11.—Thermo-Electric Bridge.

adjustments are correct. During an observation, therefore, the battery electromotive force opposes that of the couple and the readings of the bridge-wire and step resistance taken together measure the electromotive force of the couple when the galvanometer, G, shows a balance. The scale of the bridge-wire is graduated to read to 10 microvolts, and single microvolts may be read by estimation. The majority of the observations were taken when using a D'Arsonval galvanometer, giving, on a scale distant 110 centimetres, a deflection of 560 milli-

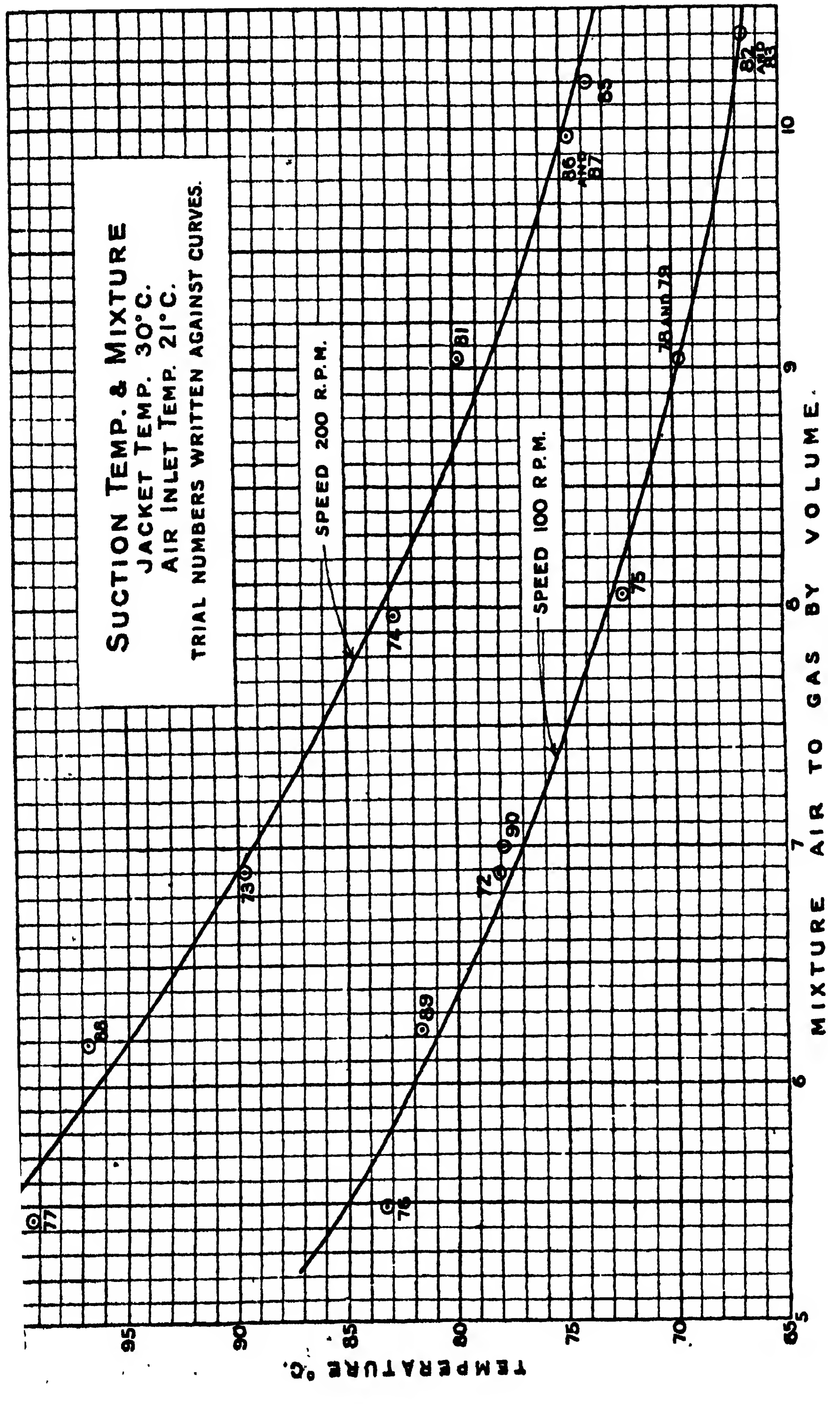
SUCTION TEMP. & MIXTURE
JACKET TEMP. 30°C.
AIR INLET TEMP. 21°C.
TRIAL NUMBERS WRITTEN AGAINST CURVES.
SPEED 200 R.P.M.
SPEED 100 R.P.M.
MIXTURE AIR TO GAS BY VOLUME
TEMPERATURE °C.

FIG. 12.

metres for 1 microvolt. The contact-maker used with this apparatus is one devised by Professors Callendar and Dalby, which has already been described and illustrated in fig. 3.

Suction Temperature.

Direct measurements of the suction temperature were made at the City and Guilds (Engineering) College during the session 1912-13 on a Crossley gas-engine with a cylinder 7 inches in diameter, stroke 14 inches, and with a compression ratio of 4·8. The object of the experiment was to show how the suction temperature varied with the speed, with the jacket temperature, and with the mixture.

The apparatus with which the measurement was made has been already described (see pages 180, 181, 182, and 183). The results of the experiments are shown by the curves fig. 12. It is proposed to repeat these experiments on engines of more modern type and with higher compression ratios as soon as the development of the new laboratories at the College render it possible to do so.

The Cyclical Variation of the Temperature of the Charge in a Gas-engine Cylinder.

An example has already been given of the method of determining the cyclical variation of the temperature of the charge in a particular experiment, deducing it from the temperature measured at a point on the compression curve in combination with accurate indicator diagrams. The experiment was made at the City and Guilds (Engineering) College on the gas-engine already referred to. The engine *is not of recent construction and therefore the* compression ratio, viz. 4·8, is low compared with the ratios of gas-engines of more modern construction. Dr. Coker and Mr. Scoble have measured the cyclical variation of temperature on a more modern engine constructed by the National Gas-Engine Company in 1907. This engine has a cylinder 7 inches in diameter and a stroke of 15 inches. The maximum volume occupied by the charge is 5·8 times the minimum volume. The method adopted was to measure directly by means of a platinum couple the temperature at various points along the compression-curve and along part of the expansion-curve, but the highest temperature had still to be measured by using the charge itself as a gas-thermometer. A value of $\frac{PV}{T}$ is selected from a point on the expansion-stroke, and the constant so found is used to calculate the higher temperatures. In this method it is unnecessary to make any calculation regarding the chemical contraction before and after explosion because the temperature is measured after the explosion, but the rate of change of temperature at the point where the temperature is measured is very great, and therefore, in comparing the two methods, it is necessary to choose between a temperature measured when the rate of change is great with a corresponding lag and no correction for chemical contraction, as against a method of measuring the temperature when the rate of change is a minimum, viz. just after the closing of the suction-valve, and allowing

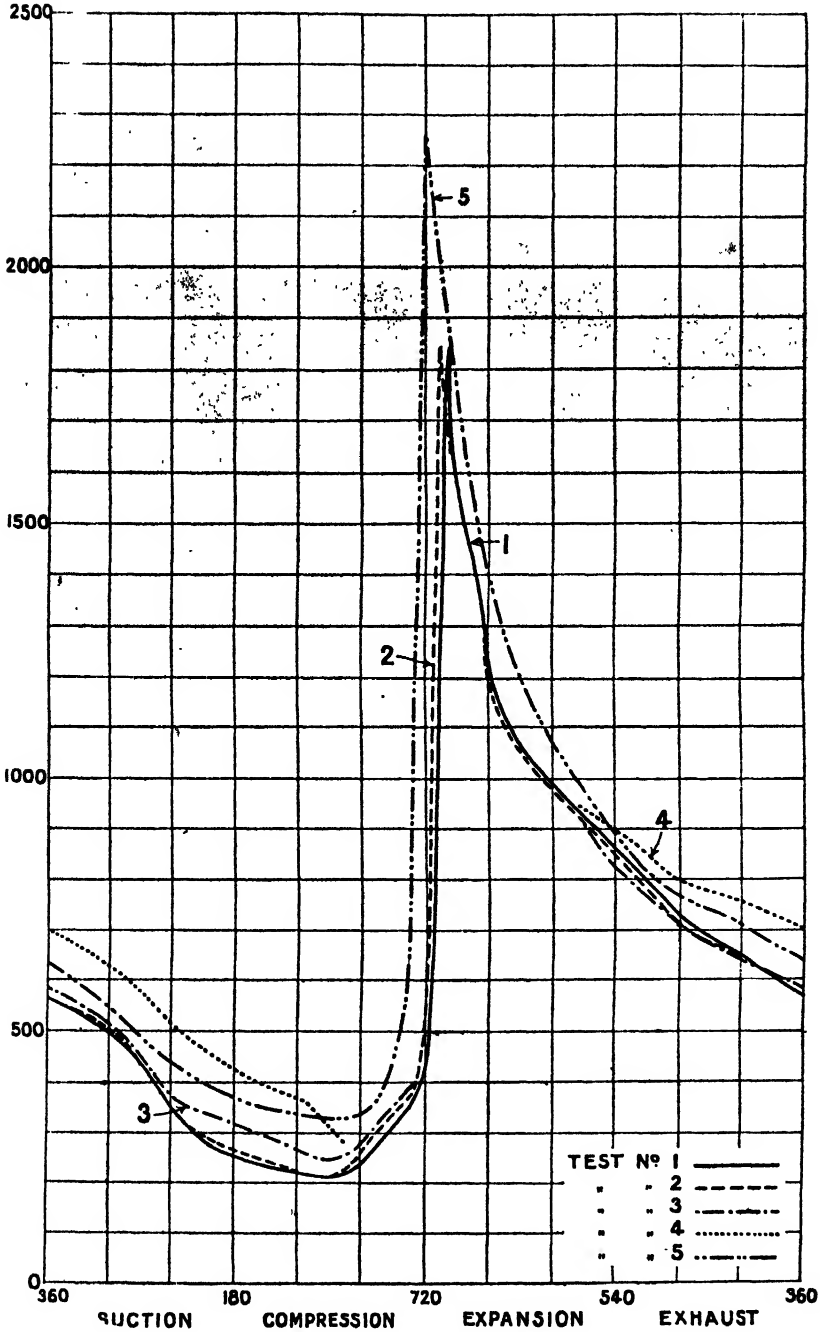
2500
2000
1500
1000
500
0
360
180
720
540
360
SUCTION
COMPRESSION
EXPANSION
EXHAUST
5
1
2
4
3
TEST Nº 1
" " 2
" " 3
" " 4
" " 5

FIG. 13.

for chemical contraction. With suitable precautions both methods can be made to give consistent results.

The curve in fig. 13 shows the temperature cycle in a gas-engine cylinder determined by Dr. Coker and Mr. Scoble when the ratio of air to gas was 7·35 to 1. The jacket-temperature was 35·6° C., and the highest temperature calculated was 1836° C.

TEMPERATURE CYCLE OF GAS CHARGE.—CONDITIONS.

Curve Number	I.H.P.	Ratio of Air to Gas	Jacket Outlet Temp. °C.
1.	10·24	7·35/1	35·6
2.	9·96	7·08/1	37·2
3.	10·11	7·13/1	81·4
4.	10·36	6·71/1	40·6
5.	10·36	5·66/1	52·8
6.	9·74	6·64/1	43·7

Application of the Work of the Committee to Practical Problems.

The application of the work of the Committee to practical problems can be illustrated in connection with the calculation of the heat exchanged between the working agent and the walls of a gas-engine cylinder.

First Law of Thermodynamics and the quantities necessary to apply it to determine heat lost or gained by the working charge during a change of state.

Let A (fig. 14) be a point on the pressure volume diagram representing the state of a working agent with regard to its pressure and volume. Let the state change along the path A, B, so that B represents the state after the change. Then

$$\left.\begin{array}{l}\text{The heat received by the}\\ \text{working agent from its}\\ \text{external environment}\\ \text{during the change of}\\ \text{state from A to B} = \text{Q}\end{array}\right\} = \left\{\begin{array}{c}\text{Mass of}\\ \text{charge}\end{array}\right\} \times \left\{\begin{array}{c}\text{The change}\\ \text{of its inter-}\\ \text{nal energy}\\ \text{per pound}\end{array}\right\} + \left\{\begin{array}{l}\text{The work}\\ \text{done by}\\ \text{the agent}\\ \text{on its en-}\\ \text{vironment}\end{array}\right\} \quad (1)$$

That is, reckoning in thermal units,

$$Q = M(E_B - E_A) + \frac{Z}{J} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

In which Q is measured in pound calories.
M is the mass of the charge in pounds.
E_B is the internal energy of the charge in its final state.
E_A is the internal energy of the charge in its initial state.
Z is the work done by the agent on its environment measured in foot-pounds.
$J = 1{,}400$.

Earlier it was assumed that the specific heat of the gas used in the gas-engine cylinder was constant, and that the change of internal energy was determined by the change of temperature only. With this assumption the first term on the right-hand side of the equation was

reckoned by merely multiplying the specific heat into the change of temperature corresponding to the change of state from A to B, the mass of the charge M being calculated from the general relation,

$$M = \frac{PV}{T} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

corresponding values of P, V, and T being taken from any point on the path where they could be determined. It is known, however,

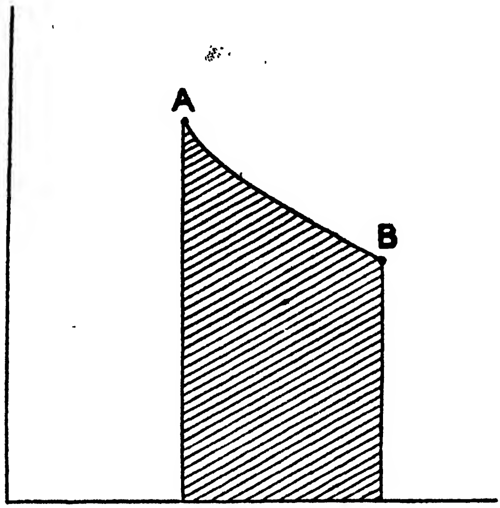

FIG. 14.

that the specific heat is variable, and the Committee began their work by reviewing all the available experimental data in connexion with the subject. Several members of the Committee were themselves carrying out researches in relation to this problem at the same time.

Data found to enable this Determination to be made.

The aim of the Committee was to ascertain the true value of the specific heat at constant volume, K_v, or, to put it in another way, to ascertain the relation between the internal energy of the gas and its temperature. In dealing with gas-engine problems it is more convenient to combine equations (1) and (2) into a single expression in which the specific heat is given not in terms of the unit of mass, but in terms of the unit of volume at standard pressure and temperature. Substituting in equation (3) for the standard pressure, 1 atmosphere, for the standard temperature, 273° C. absolute, and for the gas constant, $c = 96$, it will be found that the weight of a cubic foot of the working agent at standard temperature and pressure is ·081 lb., and therefore in terms of foot-pounds, and still assuming that the specific heat at constant volume is constant, equation (2) becomes,

$$JQ = \cdot 081\ JK_v\ (\text{change of temperature}) + Z.$$

The quantity 0·081 JK_v represents the change of internal energy in foot-pounds per degree change of temperature per cubic foot as measured at standard temperature and pressure. When K_v is variable and is a known function of T, say ϕ (T), the term becomes

$$0{\cdot}081\ J\int_{T_1}^{T_2}\phi(T)\,dT.$$

Values of this expression in which the lower limit T_1 is 0 degrees Centigrade can be read off the curve given in fig. 15, which is taken from the first Report.

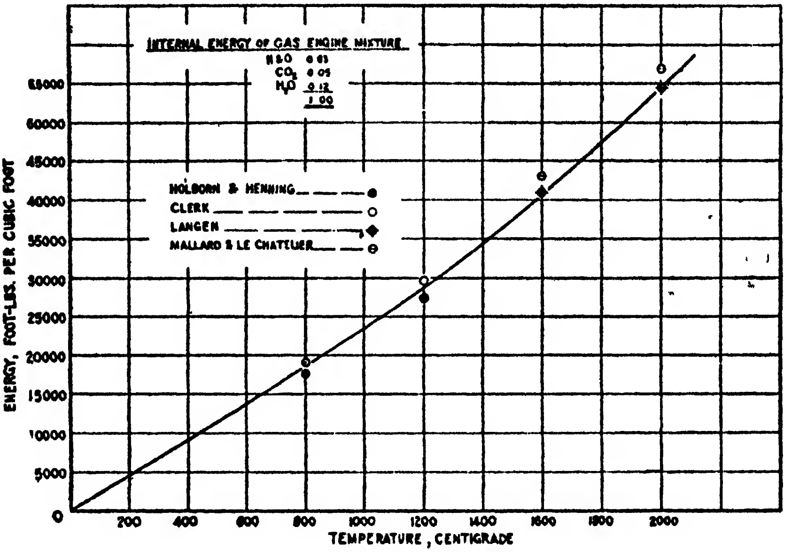

Fig. 15.

To use this curve to find the internal energy corresponding to a given state-point it is necessary to measure the pressure P and volume V from a PV diagram, and also to determine the absolute temperature T. The corresponding volume at standard temperature and pressure is then calculated from the equation,

$$V_0 = \frac{VP}{T}\,\frac{T_0}{P_0}$$

This calculated value of V_0 when multiplied by the internal energy as given by the curve for the temperature T gives the internal energy of the gas corresponding to the given state-point.

Symbolically let

E_A = internal energy corresponding to the position of a state-point A.
V_{A_0} = the corresponding volume measured at A reduced to standard temperature and pressure, and
Y_t = the ordinate of the curve measured at the temperature corresponding to the temperature of the state-point, then

$$E_A = V_{A_0}\ Y_t$$

The position of the points A and B on the PV diagram gives no indication of the temperature at A or B. If the temperature at one of the points, however, is known, then the temperature at the second point can be calculated from the relation

$$\frac{P_A V_A}{T_A} = \frac{P_B V_B}{T_B} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

This relation expresses the characteristic equation for gases, and is quite independent of the specific heat of the gases concerned. It applies to all positions of the state-point in the PV diagram provided that the following two conditions are satisfied:—

Condition 1. That there is no change in density of the gas such as may be produced by some change in its chemical constitution.

„ 2. That the weight of the working agent during the change of state from A to B is constant.

It is fundamentally important, therefore, to be able to measure by direct observation the temperature corresponding to at least one position of the state-point in the diagram, because by means of this temperature and the relation expressed in equation (4) the temperature corresponding to any other position of the state-point in the diagram can be calculated, providing always that the conditions 1 and 2 are not violated during the change of state. If the first condition is violated there is a small change of volume caused by chemical action as the state-point moves from A to B, and in order to calculate the magnitude of this change it is necessary to have a chemical analysis of the gas before and after chemical action. When these analyses are known a correction can be made and equation (4) can still be applied to calculate the temperature. This kind of action has to be reckoned with, for example, if the state-point A is on the compression-curve of a gas-engine and the state-point B is on the expansion-curve.

The earlier part of this report shows that the Committee have given a good deal of consideration to the subject of the direct measurement of temperature, and that individual members have worked at the problem successfully. Examples have been given earlier in the report of methods which have been applied and are being used in the researches which are now being carried out. This example shows how the equation (4) is used to calculate the temperature for different positions of the state-point B from observations of a single temperature. The single temperature which it is most useful to know is the suction-temperature, and this may be defined as the temperature of the charge in the cylinder just after the admission valve is closed. There is then a definite weight of charge in the cylinder at a definite pressure and volume, and at a definite temperature. Allowing for the chemical contraction, equation (4) can be applied along the expansion-curve.

The Committee have examined into the question of leak of charge, and have come to the conclusion that in most cases in a modern engine it is a negligible amount when proper precautions are taken.

These considerations show how important the suction temperature is in combination with the indicator diagram, as from this temperature and the pressure and volume given by the diagram the state of the working agent all through the cycle can be determined, at least approximately.

The values of the suction temperature for a particular engine are exhibited in fig. 12 above, and a diagram of the kind would be useful in connexion with any internal-combustion motor.

To resume, it can now be assumed that it is possible to fix a temperature for one particular position of the state-point A, and then the temperature at the end of the change of state B, if not observed, can be calculated. With a knowledge of those temperatures the internal energy of the working agent can be read off from the curve (fig. 15), and then the first term on the right side of the equation, viz.

$$E_B - E_A = \text{change of internal energy}$$

is determined.

The value of the second term on the right side of equation (1) is merely the value of the shaded area under the path AB expressed in foot-pounds. Consequently, from a pressure-volume diagram giving the initial and final conditions of the working agent and the path of the state-point in between, together with the temperature corresponding to one position of the state-point, the right side of the equation can be determined and the heat gained or lost by the working agent during the change can therefore be computed. If there is no gain or loss of heat the work done is done at the expense of the internal energy of the working agent itself. One of the main objects of the Committee has been to extend our knowledge of the physical constants of the gases by the careful examination of methods, apparatus, and results of various investigators, including members of the Committee, and change of state of the working charge in a gas-engine can now be followed with a degree of accuracy which hitherto has been impossible.

A diagram from an actual gas-engine shows the PV changes during the whole of the four-stroke cycle, but the method explained above can only be applied to determine the heat exchanges during that part of the cycle when the weight of charge enclosed in the cylinder is constant—*i.e.* during the period between the closing of the suction-valve and the opening of the exhaust-valve. There is no difficulty in applying the method practically to a change of state along the compression-curve because the conditions 1 and 2 above are fulfilled. There is no chemical change and the weight of charge is constant. Applying the method to the analysis of the expansion-curve, however, there is difficulty. The left side of equation (1), Q, gives the heat gained or lost by the gas during a change of state. Q includes the heat gained by combustion as well as the heat gained or lost from outside, so that it must be written

$$Q = O + C$$

where O represents the heat gained or lost to the outside, and C repre-

sents the heat produced by combustion during the change. The difficulty is to separate these two during a change of state along the expansion-line. It is probable that combustion is not quite complete at the point of maximum pressure; in fact some combustion may be going on right up to the point at which the exhaust-valve opens. If, therefore, two points are taken on the expansion-curve and this method of analysis is applied, neglecting O, the heat loss determined will obviously be too great.

An analysis of the diagram by this method will be found in Dr. Clerk's Gustave Canet lecture, and need not, therefore, be further pursued.

Attention may be specially drawn to the curves in fig. 12, which show the results of trials made for the purpose of ascertaining the relationship between the suction temperature and the strength of the mixture used and on the speed. When the mixture is 9 parts of air and 1 part of gas by volume the suction-temperature is about 70° C. at a speed of 100 revs. per minute. At 200 revs. per minute the suction temperature is increased to 78½° C. At the constant speed of 200 revs. per minute the temperature gradually increases as the mixture becomes richer; with a 10 to 1 mixture the temperature is 75° C., and this increases to 96½° C. with a 6 to 1 mixture. At the lower speed the change in temperature is almost as great for a corresponding change in the mixture, namely from 67½° C. to 82° C. With a modern engine using a higher compression it is probable that the temperatures would be generally higher. Fig. 13 shows the cyclical variation of temperature as determined by Dr. Coker on a more modern engine, and the suction temperatures given by him are of the order of 200° C. Dr. Coker explains this high suction temperature as being partly due to the retention of hot gas and partly due to the long exhaust-pipe which was used.

Dalby and Callendar's experiments have shown that when using rich mixtures the maximum temperature in the cylinder is probably about 2000° C., and these results have been confirmed by Coker and Scoble. For the mixtures used in ordinary working conditions the experiments of Dalby, Callendar, Coker, and Scoble show that the temperature is about 1800° C. It is hoped to continue the experiments on temperature measurements when engines of more modern construction have been installed in the new engine laboratory of the City and Guilds (Engineering) College.

The concentration of research on the accurate measurement of temperature is a necessary step towards a more certain knowledge of the specific heat of gases at high temperatures; and the vital importance of this subject is indicated by the brief explanation given above of the method by which the determination of heat exchange between the working charge and the walls of the cylinder can be made. So far the Committee have only been able to present the curves given in fig. 15 as representing the most reliable data available. The practical use to which the curve can be put is illustrated by using the data given by it to find the efficiency of an engine working on the Otto cycle without loss of heat assuming that the mixture used is that

specified near the curve in fig. 15, this mixture being very much nearer the actual mixture used in a gas-engine than air.

Thermal Efficiency.

$\frac{1}{r}$	Efficiency calculated from the curve and for the mixture given in fig. 13	Efficiency of the air standard
$\frac{1}{2}$	·187	·242
$\frac{1}{3}$	·273	·356
$\frac{1}{4}$	·337	·426
$\frac{1}{5}$	·384	·475

The Committee are of opinion that they can usefully continue their work by organising research on the lines which have been foreshadowed in this report. The Committee recommend, therefore, that they be again re-appointed, and that, in view of the expensive nature of the research and the organisation involved, the sum of 100*l.* be granted to them.

Stress Distributions in Engineering Materials.—Report of the Committee, consisting of Professor J. PERRY (*Chairman*), Professors E. G. COKER *and* J. E. PETAVEL (*Secretaries*), Professor A. BARR, Dr. C. CHREE, Mr. GILBERT COOK, Professor W. E. DALBY, Sir J. A. EWING, Professor L. N. G. FILON, Messrs. A. R. FULTON *and* J. J. GUEST, Professors J. B. HENDERSON *and* A. E. H. LOVE, Mr. W. MASON, Sir ANDREW NOBLE, Messrs. F. ROGERS *and* W. A. SCOBLE, Dr. T. E. STANTON, *and* Mr. J. S. WILSON, *to report on Certain of the More Complex Stress Distributions in Engineering Materials.*

THE reports presented at the Birmingham Meeting of the Association led the Committee to the view that the co-ordination of the results of various researches was rendered difficult by the diversity of the materials used in the tests. It was therefore thought desirable to obtain complete and systematic data with regard to three definite materials, namely, a mild steel, a ·3 per cent. carbon steel, and a steel alloy.

In accordance with a resolution passed at the meeting of December 19, 1913, a stock of three tons standard steel has been obtained for the Committee by Dr. F. Rogers. This consists of:—(1) Dead mild steel (carbon ·12 per cent.); (2) Axle steel (carbon ·3 per cent.); (3) Nickel steel.

Some of the steel has already been sent to various members of the Committee, and in due course full information will be available with regard to the behaviour of the three materials under a large number of different tests.

The mild steel was kindly presented to the Committee by Messrs. Steel, Peech, and Tozer, and the axle steel by Messrs. Taylor Bros.

Information with regard to the manufacture of the standard steels is given in an Appendix.

A report on the 'Experimental Determination of the Distribution of Stress and Strain in Solids' has been presented by Professors Coker and Filon.

A paper on the 'Internal Stresses in a Built-up Steel Compression

Member,' by Mr. H. Delépine, has been communicated by Professor Petavel, and will be read at the meeting.

A number of members of the Committee have, during the past year, been engaged on subjects dealt with in last year's report, but in most cases the experimental work is not yet completed.

The subjects under investigation are the following :—

Professor Coker and Mr. Scoble : Shear Tests.

Mr. Cook : Tests of the Physical Constants of the Standard Steels.

Messrs. Cook and Robertson : Further Work on the Strength of Thick Cylinders.

Mr. Fulton : Alternating Stress at Low Frequencies.

Mr. Guest and Professors Dixon and Lea : Combined Stresses.

Mr. Mason : Repeated Combined Stresses.

Dr. Rogers : Alternating Stress, Heat Treatment, and Microscopical Examination.

Mr. Scoble : Repeated Combined Stresses.

Dr. Stanton : Repeated Shear Tests.

Mr. Mason has installed, in the Engineering Laboratory at the University of Liverpool, a machine specially designed for experimental work on alternating bending, alternating torsion, and simultaneous alternating bending and torsion. He has also constructed an apparatus for measurement of hysteresis.

Dr. Stanton has made arrangements to test the standard steels, firstly by reversals of simple shearing stress, then by superimposing bending and direct stresses.

Mr. Guest and Professors Dixon and Lea have completed the erection of their apparatus, and are engaged in preliminary experimental work.

The Committee ask to be re-appointed with a grant of 100*l*.

Appendix.

Outline of Manufacture of the Standard Steels.
By Dr. F. Rogers.

No. 1 Steel. (·12 per cent. Carbon.)

The materials used in the manufacture of this steel are hematite pig iron, steel scrap and ore of the purest descriptions, melted very carefully in the acid open hearth furnace.

The composition is adjusted by the addition of ferro-manganese, after which the metal is cast into ingot-moulds. The ingots are then rolled, with several heatings, into bars, which are reeled when black-hot, giving a straightening and burnishing effect without injuring the steel.

This metal is suitable for high-class mild steel.

The bars supplied to the Committee are the whole usable portion of two ingots, and weigh nearly 22½ cwts.

No. 2 steel (·3 per cent. carbon).

Report not yet received.

No. 3 steel (3½ per cent. nickel).

Report not yet received.

Experimental Determination of the Distribution of Stress and Strain in Solids. By Professors Filon *and* Coker.

Very little has been done hitherto in the way of determining directly the distribution of stresses and strains in the interior of an elastic solid. The

investigations which have been made deal almost exclusively with the more restricted case of two-dimensional stress and strain, or of stress and strain in a thin plate parallel to the faces of the plate itself, a problem known to elasticians as that of 'generalised plane stress.'[1]

In these cases two methods have proved available. The first method consists in measuring directly the deformations of the body studied, by observing the actual distortion of a face of the solid parallel to the plane of strain. In practice this may be done by ruling this face into squares and observing, with a kathetometer or micrometer, the relative shifts of various parts of the network. From these, the extent by which the angle at a node of the network has been changed from a right angle can easily be found, and this quantity, as is well known, measures the shearing strain (or 'slide,' according to a terminology followed by many writers on elasticity, who reserve the word 'shear' to denote the shearing-stress).

In this way values of the shearing-strain are obtained at the various nodes of the network. Again, the changes of distance between adjacent

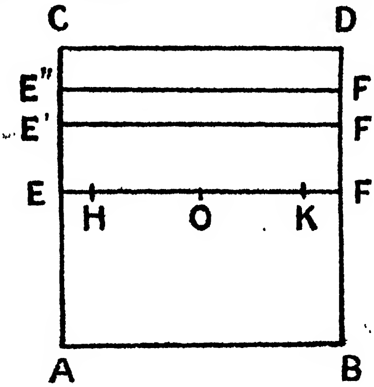

FIG. 1.

nodes can be found, and from these, if the squares of the network are sufficiently small, the extensions at the various nodes, parallel to the lines of the net, can be obtained.

The plane-strain can, therefore, be mapped out over the whole face of the solid which is under observation. If this method is to give satisfactory results it must be applied to materials where the strains are comparatively large. It has been applied with considerable success by Professor Karl Pearson (1) and various workers associated with him to models of dams constructed of gelatine-glycerine jelly, and in this way various results of interest in the theory of masonry dams have been obtained, although it cannot be said that the complete system of stresses in such dams is yet known with any certainty. In other cases measurements of the distortions produced in circles described on the face of a model have been used to determine the principal strains and their directions, as in the experiments of Messrs. Wilson and Gore (2).

Dr. E. N. da C. Andrade (3) has also employed a block of jelly to investigate the distribution of slide in such a block when two of its opposite

[1] Love, *Theory of Elasticity*, p. 135.

faces AB, CD (Fig. 1) constrained to remain plane and parallel and undisturbed are given a translatory displacement relative to each other, parallel to their plane.

Dr. Andrade found that along the middle plane EF of the block (half-way, that is, between the two faces whose displacement was prescribed) the distribution of slide gave two maxima at points H, K distant about one-sixth of the length from the unstressed faces perpendicular to the plane of strain, the slide falling gradually to a minimum at O.

For a section E′ F′ near the middle plane an effect of the same type occurred, but was less marked. For a section E″ F″ near the face CD where the constraint was applied the slide remained fairly uniform over the greater part of the length of the section, going down rapidly at the ends to the value zero at CD.

The problem attacked experimentally by Dr. Andrade is one of which no exact theoretical solution is known. Dr. Andrade himself attempted to fit his conditions by an approximate solution, but either through the failure of the approximation, or from some other cause, the results of observation and calculation agreed only qualitatively.

The second method used for the investigation of the distribution of stresses inside a plate subjected to stress in its own plane depends on the property, discovered by Sir David Brewster in 1816, and independently by Fresnel, that glass and other isotropic transparent substances become doubly refracting under stress.

Since then this effect has been studied by a number of observers (4). It may be taken as fairly well established that when a ray of polarised light traverses a plate stressed in its own plane, it is broken up into two components, polarised along the two lines of principal stress at the point where the ray crosses the plate, and the relative retardation of these two rays on emergence in air is

$$C\tau(P-Q),$$

where τ = thickness of the plate, P and Q are the two principal mean stresses in the plane of the plate, and C is a co-efficient depending upon the material and the wave-length of the light (5).

Clerk Maxwell (6) was the first to go fairly fully into the theory of the appearances presented when a plate under varying stress in its own plane is placed between crossed Nicols. He showed that the light is restored at all points except those for which:

(*a*) The lines of principal stress are parallel to the axes of the Nicols.

Since the condition for extinction of the light is here independent of the wave-length, these lines will be quite black. These may be called the lines of equal inclination or isoclinic lines.

(*b*) The principal stress-difference has such a value that $C\tau(P-Q)$ is an exact multiple of the wave-length.

These will be lines of equal principal stress-difference, and will give a different set of lines for different wave-lengths. They are thus, in general, brilliantly coloured, the same stress-difference corresponding to the same tint. The only exception is the line corresponding to $P-Q=0$.

These may be called (following Maxwell) the *isochromatic* lines, the black line corresponding to $P-Q=0$ being called the *neutral* line.

Observations of the isoclinic lines have the advantage that these lines are exhibited under comparatively small stress and are independent of the co-efficient C. Their use does not, therefore, require straining the

material to an extent likely to produce permanent set, and they can be shown by comparatively thin specimens. Also they do not require any previous investigation of the co-efficient C for the given material, or of its dependence upon the wave-length.

In theory observation of the isoclinic lines is sufficient to determine the stress system, provided we have information as to the actual stresses at a very limited number of points (7). Such information is generally available from the known boundary conditions.

On the other hand, the calculations required to actually deduce the stresses from the isoclinic lines are complicated, and are very difficult to apply to cases where the data are expressed by purely empirical curves.

The isoclinic lines are, therefore, better suited to experimental verification of stress distribution already known from theory, and for which the theoretical isoclinic lines can be calculated beforehand and compared with observation. They have been so used by M. Corbino and Trabacchi (8) using rings of gelatine to verify Volterra's (9) theory of internal strains in a multiply connected elastic solid; and also by Filon (10), who used glass beams to verify the ordinary theory of stresses in a beam at a distance from points of isolated loading, and also his own theory of the distribution of stress in a beam near a point of isolated loading. Both Corbino and Trabacchi, and Filon found that their experimental results confirmed the predictions of the theory of elasticity (11). Carus Wilson (12), who used in his investigation both the isoclinic and the isochromatic lines, was the first to apply the optical method to discover the laws of stress distribution in a glass beam, doubly supported and centrally loaded.

He gives a drawing of the lines of principal stress in such a beam, but does not use them further, and restricts his comparison of theory with experiment, to the stresses in the cross-section immediately under the load; the theory with which he compares his results was originally given by Boussinesq (13), and treats the height of the beam as infinitely thick. Sir G. G. Stokes gave, in a note to Carus Wilson's paper, an empirical correction to Boussinesq's theory. An exact theory of this problem has since been given by Filon (14).

The use of the isochromatic lines and generally of experiments depending upon tint has this advantage, that it yields directly the value of the stress-difference P—Q. If this be combined with a determination of the direction of principal stress at each point, then considerable direct information is given at once, and some cases of practical importance have been examined by Hönigsberg and Dimmer (15).

The determination both of P—Q and of the directions of principal stress may be combined in one measurement, which is very simply made by means of an apparatus due to Coker (16). Coker uses a thin celluloid plate, cut to represent an engineering structure in which it is desired to investigate the stresses. This is a more easily worked material than glass, and a lesser thickness is required, as its stress-optical co-efficient is considerable. To obtain a measure of the stress-difference at any point a tension member is placed in front of the strained model, in a direction corresponding to one of the principal axes of stress, and the colour effect produced in the loaded model is neutralised by applying a sufficient load to this calibrating member. The tensional stress T affords a measure of the difference of the principal stresses (P—Q) subject to a small correction when (P—Q) and T have different signs.

An improved way of doing this, which saves these repeated adjust-

ments of T, is to use a test-piece under pure flexure (without shear) in its own plane. This can be readily produced in a straining frame as in the accompanying diagram. The stress will then vary linearly from P to Q and may be read off along a scale PQ, which can be previously calibrated against a specimen under known tension.

A little sideways shift of the test-plate is then all that is required to compensate the stress-difference at any given point, provided that the direction of principal stress had been found previously.

Coker has used a calibration tension member to determine the distribution of stress in plates of various shapes—for example, in tension specimens

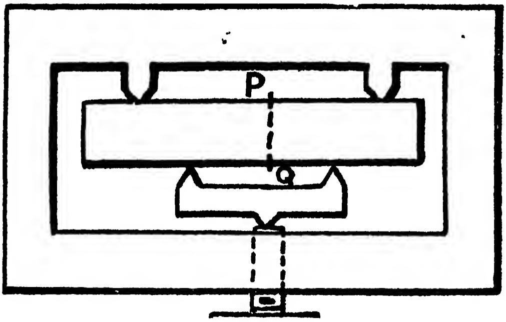

Fig. 2.

pierced with circular holes, decks of ships with various openings, cement briquettes, &c. (17). He has also (18) investigated Andrade's problem of the block whose opposite faces slide with regard to one another remaining undistorted, and he obtains by this optical method a distribution of shear very similar to that obtained by Andrade from direct measurements of the slide. Mr. Scoble and he have also applied this method to determine the distribution of stress due to a rivet in a plate (19).

The photo-elastic determination of stress carried out in this way does not, however, determine the stress in the plate completely. It will be noticed that all the method gives is the principal *stress-difference* at any point. If each principal stress at a given point be increased by any arbitrary quantity, the appearances are in no wise altered. To obviate this, Coker has used the stretch-squeeze effect in the plate to measure the sum P—Q of the principal stresses, a suggestion due originally to Mesnager (20). For clearly, if τ be the thickness of the plate, η Poisson's ratio, the plate, at the point where the principal stresses are P, Q, will become thinner by an amount $\eta\tau(P+Q)$ an amount which is small, but with delicate instruments not impossible to measure.

It will be noticed that this provides yet a third method for exploring the field of stress in a plate.

There is, however, no necessity for doing this, as the information derived from the known values of the stress-difference and the direction of the lines of principal stress can be readily applied to find the complete system of stresses.

Let the axes of x and y be taken in the plane of the plate. Let P and Q now denote the normal stresses across elements dy and dx respectively, S the shearing stress across either of the above elements. Then, if the

lines of principal stress make an angle a with the axes, and if R is the principal stress-difference, it is well known that

$$P-Q=R\cos 2a$$
$$2S=R\sin 2a.$$

Thus a determination of R and a at every point leads to the value of S at all points.

On the other hand, considering the equilibrium of a small rectangle dx, dy and neglecting body-forces, we have the well-known body stress equations for generalised plane strain,

$$\frac{\delta P}{\delta x}+\frac{\delta S}{\delta y}=0, \qquad \frac{\delta S}{\delta x}+\frac{\delta Q}{\delta y}=0.$$

Now, at a point of the boundary, all the stresses will be known.

For the normal stress across an element of the boundary where the outwards normal makes an angle with the axis of x is

$$P\cos^2\theta+Q\sin^2\theta+2S\cos\theta\sin\theta$$

$$=\frac{P+Q}{2}+\frac{P-Q}{2}\cos 2\theta+S\sin 2\theta.$$

S and P—Q being known from optical data, and the normal stress across the boundary being also known from the boundary conditions, the above equation determines P+Q and hence (P—Q being known) P and Q.

Consider now a point A of the plate. Draw a line through A parallel to the axis of x to meet the nearest boundary at a point A_0 (x_0, y).

Then, integrating the equation

$$\frac{\delta P}{\delta x}+\frac{\delta S}{\delta y}=0$$

along the line A_0 A, we find

$$P-P_0=-\int_{x_0}^{x}\frac{\delta S}{\delta y}\,.\,dx,$$

where P_0 is the value of P at A_0.

Similarly, if a line through A parallel to the axis of y meets the nearest boundary at a point B_0 (x, y_0) when the value of Q is Q_0,

$$Q-Q_0=-\int_{y_0}^{y}\frac{\delta S}{\delta x}\,.\,dy.$$

Now, if we know the value of S at all points, the values of the partial differential co-efficients $\frac{\delta S}{\delta x}$, $\frac{\delta S}{\delta y}$ can be obtained approximately by taking differences. P and Q can then be found as above by the ordinary process of graphical integration, P_0, Q_0 being known, as explained. This method can be used with any set of experimental data, provided only that these are accurate enough to allow of differences being taken to calculate $\frac{\delta S}{\delta x}$, $\frac{\delta S}{\delta y}$. In any case, before actually applying the method, the curves for S when either x = constant or y = constant should be 'smoothed' so

as to take out accidental inequalities. A check on the accuracy of the calculation is easily provided, for the calculated $P-Q$ should agree with the value optically observed.

In many problems it is known that one of the normal stresses is throughout very small. In this case, if Q, say, is nearly zero, we have $P=R \cos 2\alpha$, and the stress difference leads easily to the complete system of stresses. This assumption has been made by Coker in his earlier papers, but it would seem desirable to justify it more fully.

NOTES.

(References to these are given in the text.)

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(4) Sir David Brewster: 'Phil. Trans.' 1816, p. 156. 'Annales de Chimie et de Physique,' vol. xx. Fresnel: 'Œuvres d'Augustin Fresnel,' tome 1, p. 713. F. E. Neumann, 'Abh. d. k. Acad. d. Wiss. zu Berlin,' 1841, vol. ii., p. 50–61. See also 'Pogg. Ann.' vol. liv. John Kerr: 'Phil. Mag.,' 1888, ser. 5, vol. 26, No. 161. G. Wertheim: 'Annales de Chimie et de Physique,' ser. 3, vol. xl., p. 156.

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(6) Clerk Maxwell: 'Trans. Roy. Soc. Edin.,' vol. xx., 1853, p. 1172; or 'Collected Papers,' vol. i.

(7) A proof of the statement in the text is as follows:—Let E be the stress function for generalised plane stress (Love: 'Theory of Elasticity,' pp. 86 and 446), P, Q, S the mean stresses $\widehat{xx}$, $\widehat{yy}$, $\widehat{xy}$ in the usual notation, R the principal mean stress-difference, ϕ the angle which the lines of principal stress make with the axes.

Then it is known that

$$R^2=(P-Q)^2+4S^2$$

$$\tan 2\phi=2S/P-Q$$

$$2S=P \sin 2\phi \qquad P-Q=R \cos 2\phi.$$

Also the mean stresses are given in terms of the stress function by

$$P=\frac{\delta^2 E}{\delta y^2}, \qquad Q=\frac{\delta^2 E}{\delta x^2}, \qquad S=-\frac{\delta^2 E}{\delta x, \delta y}.$$

Using the transformations

$$2\xi = x + \iota y$$
$$2\eta = x - \iota y$$

we find readily

$$Q + \iota S = \frac{\delta}{\delta x}\left(\frac{\delta E}{\delta \xi}\right) \qquad Q - \iota S = \frac{\delta}{\delta x}\left(\frac{\delta E}{\delta \eta}\right)$$

$$S + \iota P = -\frac{\delta}{\delta y}\left(\frac{\delta E}{\delta \xi}\right) \qquad S - \iota P = -\frac{\delta}{\delta y}\left(\frac{\delta E}{\delta \eta}\right)$$

$$\therefore \quad Q - P + 2\iota S = \frac{\delta^2 E}{\delta \xi^2} \quad (1) \qquad Q - P - 2\iota S = \frac{\delta^2 E}{\delta \eta^2} \quad (2)$$

$$Q + P = \frac{\delta^2 E}{\delta \xi \,.\, \delta \eta} \quad (3)$$

From (1) and (2)

$$-R\epsilon^{-2\iota\phi} = \frac{\delta^2 E}{\delta \xi^2} \qquad -R\epsilon^{2\iota\phi} = \frac{\delta^2 E}{\delta \eta^2}$$

$$\therefore \quad \epsilon^{4\iota\phi}\frac{\delta^2 E}{\delta \xi^2} = \frac{\delta^2 E}{\delta \eta^2} \quad (4)$$

Now, the isoclinic lines give ϕ as a function of x, y and therefore of ξ, η for every point.

On the other hand, it is well known that E satisfies the equation

$$\overset{4}{\nabla}_{x,y} \,.\, E = 0$$

or

$$\frac{\delta^4 E}{\delta \xi^2 \,.\, \delta \eta^2} = 0,$$

of which the solution is

$$E = E_1(\xi) + E_2(\eta) + \eta E_3(\xi) + \xi E_4(\eta) \quad (5)$$

E_1, E_2, E_3, and E_4 being arbitrary functions.

(4) then gives

$$\epsilon^{4\iota\phi(\xi,\eta)}\Big[E_1''(\xi) + \eta E_3''(\xi)\Big] = E_2''(\eta) + \xi E_4''(\eta) \quad (6)$$

Putting $\eta = 0$, $\xi = 0$ successively in the identity (6)

$$E_1''(\xi) = \epsilon^{-4\iota\phi(\xi,0)} \,.\, \Big[E_2''(0) + \xi E_4''(0)\Big] \quad (7)$$

$$E_2''(\eta) = \epsilon^{4\iota\phi(0,\eta)} \,.\, \Big[E_1''(0) + \eta E_3''(0)\Big] \quad (8)$$

Differentiating (6) with regard to ξ, η and then putting $\xi=0$ and $\eta=0$ respectively, we find

$$E_4''(\eta)=\left\{\frac{\delta}{\delta\xi}\cdot \epsilon^{4\iota\phi}\left[E_1''(\xi)+\eta E_3''(\xi)\right]\right\}_{\xi=0}$$

$$E_3''(\xi)=\left\{\frac{\delta}{\delta\eta}\epsilon^{-4\iota\phi}\left[E_2''(\eta)+\xi E_4''(\eta)\right]\right\}_{\eta=0}$$

i.e.,

$$E_4''(\eta)=4\iota\left(\frac{\delta\phi}{\delta\xi}\right)_{0,\eta}E_2''(\eta)+\epsilon^{4\iota\phi(0,\eta)}\left\{E_1'''(0)+\eta E_3'''(0)\right\} \quad (9)$$

$$E_3''(\xi)=-4\iota\left(\frac{\delta\phi}{\delta\eta}\right)_{\xi,0}E_1''(\xi)+\epsilon^{-4\iota\phi(\xi,0)}\left\{E_2'''(0)+\xi E_4'''(0)\right\} \quad (10)$$

Assume $E_1''(0)=A$, $E_3''(0)=B$, $E_1'''(0)=C$, $E_3'''(0)=D$.

Equations (7)–(10) determine $E_2''(\eta)$, $E_4''(\eta)$ and hence $E_1''(\xi)$, $E_3''(\xi)$ as homogeneous linear functions of A, B, C, D.

Hence $E=Ae_1+Be_2+Ce_3+De_4+\alpha\xi+\beta\eta+\gamma\xi\eta+\delta$, where e_1, e_2, e_3, e_4 are now known functions and α, β, γ, δ are arbitrary constants.

The terms in α β δ do not affect the stresses and may be dropped.

The term $\gamma\ \xi\ \eta$ may add γ to P+Q.

If, now, the value of any stress be known at a given point, this leads to a linear equation between A, B, C, D, γ.

Hence the complete specification of the stress at two points leads to six equations for A, B, C, D, γ in like manner, if we consider the conditions at the boundary, where two of the stresses are in general known, the conditions at three points give six equations. In either case we have more than enough equations to determine A, B, C, D, γ.

Thus the stress conditions at a few points, together with the isoclinic lines, determine the stress system completely.

(8) O. M. Corbino and Trabacchi: 'Rendiconti Acad. dei Lincei,' vol. 18, 1909. See also letter by O. M. Corbino in 'Nature,' Jan. 16, 1913.

(9) Volterra: 'Annales de l'Ecole Normale de Paris,' 1907.

(10) L. N. G. Filon: The Investigation of Stresses in a Rectangular Bar by Means of Polarised Light, 'Phil. Mag.,' Jan. 1912.

(11) Volterra, *loc. cit.* Note (8); Corbino, *loc. cit.* Note (7). Filon, *loc. cit.* Note (9); also Filon, 'Phil. Trans. A.,' vol. 201, pp. 63–155.

(12) Carus Wilson: 'Phil. Mag.,' ser. 5, Dec. 1891.

(13) Boussinesq: 'Comptes Rendus,' vol. 114, pp. 1510–1516. See also Flamant: 'Comptes Rendus,' vol. 114, pp. 1465–1468.

(14) L. N. G. Filon: On an Approximate Solution for the Bending of a Beam of Rectangular Cross-section under any System of Load: 'Phil. Trans. A.,' vol. 201, pp. 63–155.

(15) O. Hönigsberg and G. Dimmer: Interferenzfarben beanspruchter durchsichtiger Körper. O. Hönigsberg: Unmittelbare Abbildung der neutralen Schichte bei Biegung durchsichtiger Körper in zirkularpolarisierten Licht, 'International Association for Testing Materials,' Brussels Congress, 1906.

(16) E. G. Coker: The Determination by Photo-elastic Methods, of the Distribution of Stress in Plates of Variable Section, with some Applications to Ships' Plating, 'Transactions of the Institution of Naval Architects.' See especially pp. 9–11.

(17) E. G. Coker: Paper cited in Note 14 and the following:—The Optical Determination of Stress, 'Phil. Mag.,' 1910. The Distribution of Stress at the Minimum Section of a Cement Briquette, 'International Association for Testing Material,' 1912. The Effects of Holes and Semi-circular Notches on the Distribution of Stress in Tension Members, 'Physical Society of London,' 1913.

(18) E. G. Coker: An Optical Determination of the Variation of Stress in a Thin Rectangular Plate subjected to Shear, 'Proc. Roy. Soc.,' 1912.

(19) E. G. Coker and W. A. Scoble: The Distribution of Stress due to a Rivet in a Plate, 'Transactions of the Institution of Naval Architects,' 1913.

(20) A. Mesnager: Mesure des efforts intérieurs dans les solides et applications, 'International Association for Testing Materials,' Buda-Pesth Congress, 1901.

The Lake Villages in the Neighbourhood of Glastonbury.—Report of the Committee, consisting of Professor W. BOYD DAWKINS (*Chairman*), Mr. WILLOUGHBY GARDNER (*Secretary*), Professor W. RIDGEWAY, Sir ARTHUR J. EVANS, Sir C. HERCULES READ, Mr. H. BALFOUR, *and* Mr. A. BULLEID, *appointed to investigate the Lake Villages in the Neighbourhood of Glastonbury in connection with a Committee of the Somersetshire Archæological and Natural History Society.* (*Drawn up by* Mr. ARTHUR BULLEID *and* Mr. H. ST. GEORGE GRAY, *the Directors of the Excavations.*)

THE fifth season's exploration of the Meare Lake Village by the Somersetshire Archæological and Natural History Society began on May 13, 1914, and will be continued until May 27 (exclusive of filling in). The ground being excavated is situated in the same field and is continuous with the work of previous years. As the report has to be sent in on May 22, while the excavations are in progress, any notes regarding the work will necessarily be incomplete and curtailed. There has been considerable difficulty this year in procuring labour, and it is proposed to reopen the excavations in September. The digging includes the examination of the ground situated to the north-east of Dwelling-Mound V., south-east of Dwelling-Mound VII., the south-west quarter of Dwelling-Mound IX., and the ground lying to the north-east of Dwelling-Mound XVIII. There is little of interest, so far, to note structurally, but the number and importance of the objects found have been well maintained.

THE RELICS.

This report is called for before the season's work is half completed, and at a time when the excavators are only on the fringe of two well-defined dwelling-mounds. Hence there is little to say with regard to the relics so far discovered.

Bone.—The bone objects include part of two needles, worked tibiæ of sheep and ox, tarsal and carpal bones of sheep, cut and perforated

shoulder-blades, polishing-bones; and a long tubular die with numbers, 3, 4, 5, 6, represented by small circular depressions on the sides, and of a similar variety to those found in the Glastonbury Lake Village; also a piece of bone cut for the formation of two dice. A bone object of a new type is the coarse comb of rude workmanship formed from a rib-bone of ox or horse; there are eight large, clumsy teeth of varied size, which bear evidence of considerable wear; it is quite of a different character from the weaving-combs so frequently found in the lake villages.

Crucibles.—Several fragments.

Bronze.—The bronze objects include a piece of bordering, two fibulæ of safety-pin design (La Tène III.), one in almost perfect condition, and a small ornamented ring-handle, perhaps of a vessel. A long tubular object formed from a strip of sheet bronze was also found, the working-end of which is trifurcated by splitting the metal for a distance of about ¾ inch, each of the divisions tapering to form a three-pointed instrument.

Iron.—Parts of knives and fragments of pointed objects.

Flint.—A few flint flakes, some with secondary chipping.

Glass.—A perfect bead of clear white glass, ornamented with three sunk spiral devices filled with a light yellow paste, has been added to the bead series; and others have been found in addition.

Antler.—Part of a polished tine, a small tubular object, a cut piece with partial perforations, two weaving-combs, 'cheek-pieces,' and tool-handles.

Kimmeridge Shale.—Part of a fluted armlet of large size, lathe-turned; and portions of three others.

Tusks.—Several boars' tusks (? wild), including one perforated.

Querns.—No complete upper or lower stone has been found, but several large portions of well-worked saddle and rotary querns have been uncovered in Mound IX.

Other Stone Objects.—Several sling-stones, found singly; a large number of whetstones; a few small smooth pebbles (perhaps *calculi*).

Spindle-whorls.—Six have been found so far, (*a*) one of baked clay, (*b*) four of lias stone, (*c*) a part of one formed from an ammonite.

Baked Clay.—Several sling-bullets of fusiform shape have been collected; also a large triangular loom-weight and fragments of others in Mound IX.

Pottery.—No complete vessel has been found, but shards are very abundant in proportion to the area dug. The rougher wares are strongly represented, but a fair number of ornamented pieces have been collected, including some new and elegant designs. Part of an ornamented pot-cover of a type previously found at Meare has been found; also at least two separate fragments of Roman ware of the 'Burtle type,' obtained from below the alluvial deposits and on the original surface of Roman times.

Animal Remains.—Large quantities of bones of domesticated animals are being collected, chiefly of young animals. Many split bones and splinters have been noticed. Bird-bones are also commonly found. A cock-spur has also come to light at Meare, which implies that

the sport of cock-fighting, common in Gaul before the Roman conquest, was carried on in the lake village of Meare, as well as in that of Glastonbury.

The Committee are desirous that they should be authorised to act for the ensuing year on the part of the British Association, and that a grant of 20*l*. should be made in aid of the exploration that is mostly paid for by local effort.

Physical Characters of the Ancient Egyptians.—Report of the Committee, consisting of Professor G. ELLIOT SMITH (*Chairman*), Dr. F. C. SHRUBSALL (*Secretary*), Professor A. KEITH, Dr. F. WOOD JONES, *and* Dr. C. G. SELIGMANN.

Professor Elliot Smith's Report.

THIS report deals with two distinct series of anthropological material, (A) one from Saqqara in Lower Egypt, and (B) the other from the Southern part of the Kerma basin in the Sudan. Both collections are of quite exceptional importance from their bearing upon the history and the racial movements in the Nile Valley.

(A.) The Committee was appointed primarily with the object of acquiring, studying, and, if feasible, transporting to England a valuable and unique series of skeletons of Ancient Egyptians, buried in mastabas of the Second and Third Dynasties at Saqqara, which Sir Gaston Maspero, Director-General of the Egyptian Government Antiquities Department, had placed at my disposal. The material was brought to light in the course of the excavations carried on for the Antiquities Department by its Senior Inspector, Mr. J. E. Quibell, who did everything in his power to facilitate and help me in my investigations. The cemetery in which the material was obtained is situated a short distance to the north of the Pyramids of Saqqara, and included the tomb of Hesy, from which the famous wooden portrait panels (now in the Cairo Museum) were obtained by Mariette Pasha many years ago. The tombs themselves are of very great interest, and will be described in detail in Mr. Quibell's official report,[1] a summary of which was read at the Dundee Meeting. They are the earliest known examples of elaborate subterranean rock-cut tombs, and range in date from the latter part of the Second Dynasty until well into the period of the Third Dynasty. At the Dundee Meeting of the Association I read Mr. Quibell's account of this cemetery, from which the following extracts[2] have been taken:—

'This is the area in which Mariette found most of his mastabas, from which much of the knowledge of the Old Kingdom has been obtained.'

[1] Excavations at Saqqara, 1910-1911, Service des Antiquités de l'Egypte.

[2] These extensive quotations, not published hitherto, are necessary to explain the importance and precise significance of the anthropological questions involved in the study of the material, to the consideration of which I shall return in the latter part of this report.

'More than 400 tombs were dug and recorded: they were singularly uniform in type and cover but a small period in time. Four were of the First Dynasty, and the rest of the Second and Third. Intrusive burials of later ages were confined to two periods, that of Thotmes III. and (probably) late Ptolemaic, and were unimportant.'

'In what follows we will confine ourselves to the Second and Third Dynasties:—

'These tombs were most varied in size, but uniform in plan. One was 50 mètres long and 30 wide, but the one I have chosen as a type was no more than 1½ mètres long, and even originally not 1 mètre high. It consists of a hollow oblong of unbaked brickwork filled in with gravel and stone chip, plastered and whitewashed externally. On the east side are two niches, the southern one being the larger and the more important. Below the mastaba was a small stairway and a subterranean chamber. The smaller tombs were often built in rows, and their position parallel with the sides of the larger ones suggested that they belonged to the servants or relatives of the great men.

'One tomb showed very clearly the origin of the later type in stone. The niche has been withdrawn into the body of the building and protected by a door. A small chamber is thus formed, and the sides of this were, no doubt, decorated with paintings; later, when stone replaced the crude brick, the scenes were made in low relief. This is the form of most of the mastabas published by Mariette; the more complex plans of the large tombs that have been left open are exceptional.

'The paths between the tombs were very narrow, hardly wide enough for one man to pass, and among the larger tombs, where there were walls 3 mètres and more high, must have formed a perilous maze. They were much used; offerings of minute quantities of food were brought on every feast day and placed before the false doors in little vases like egg-cups and saucers. Piles of these pots are found thrown away near some of the tombs.

'Very little stone-work was found. Small tanks 20 centimètres or so long occasionally remained before the niches, and in two cases an inscribed stone panel depicting the deceased seated before his table of offerings had escaped the search for lime. This panel appears in the middle of the later stelæ of the Fifth Dynasty, of which it was evidently the most important part.

'The sides of the niches may have borne painted decoration—probably did so—but no trace of this remained.

'In one mastaba, a very large one, the wall was double: the two niches were carefully built in both the inner and the outer walls, evidently in order that the inner one might retain its magical value, even if the outer one were destroyed.

'The space inside the four walls was generally filled with gravel and with stone chip from the subterranean chamber, but in some of the larger tombs the filling contained also a great number of coarse vases, many crushed by the overlying gravel, but many also unbroken. These we thought at first might have been the jars used by the workmen for food, but some of them were of unbaked clay, and could hardly

have been used at all. In other cases, too, these vases had been placed in orderly rows; in one the whole desert floor between the walls of the tomb and the edge of the shaft had been covered with these vases, with clods of black clay placed between them. It would seem, then, that these were deposits intended to supplement the furniture of the subterranean chamber.

'In the case here shown there can be little doubt. Below the filling, hidden beneath 3 mètres of gravel, we found a shallow trench ½ mètre wide, once roofed with wood. Inside it were two rows of jars or model barns, each 30 centimètres high, made of unbaked clay, and containing a brown organic powder, probably decayed corn. The trench is lined with brick, and from it a tiny tunnel, a handbreadth wide and high, leads to the mouth of the shaft. This, surely, was a secret supply of food for the dead man.

'In three of the large tombs a still more elaborate provision was made. A row of brick chambers, or tanks, was sunk in the floor of the tomb, filled with jars, and covered with a course of brick. What the jars contained is not clear; a very light organic matter, probably a fat, filled the lower half of a few, but most of them were empty when found. These chambers, or tanks, must, however, have once contained something of value, for in one tomb they had been laboriously robbed. A shaft had been sunk through the filling—in this case composed of a very tough, dried mud—into one of the chambers, and from this tunnels had been forced, sometimes through the walls, sometimes above them through the mud filling, till all the eight chambers had been rifled. The labour must have been considerable and the risk not trifling: there was nothing to show how it had been repaid.

'We now leave the structures above ground and come to the shaft.

'This was nearly always in the form of a stair, sloping down from the north or east to the chamber mouth. The stair often starts from the east, near the north niche, and bends at a right-angle half-way down; this would be practically useful while the digging was going on, as it would stop a falling stone before it acquired an awkward velocity. The shafts, like the tombs, vary much in size. Some are 12 mètres deep, some so small—1 mètre or less—that the steps would be of no practical use.

'In the larger and deeper tombs the steps are cut in the rock, are of reasonable size, and evidently served their purpose in the excavation of the chamber below; but in many of the moderate sized mastabas, those 4 to 5 mètres long, the steps are of brick, and are too narrow and fragile for a man to stand on them. Shafts and steps in the small tombs, and presumably also in the large ones, were carefully plastered and whitewashed for the funeral ceremony. In small tombs a low skirting wall a few inches in height was built round the shaft, and this, too, was whitened. The upper part, the mastaba, was built after the funeral. But in larger tombs this was not practical; the works above and below ground had to go on together, so the stair was fenced in by a separate wall.

'Shafts were generally filled with gravel, the portcullis being relied on to secure the mouth of the chamber; but in large tombs they were

filled with slabs of stone, packed in on edge, and in some cases a pavement of heavy blocks was laid in above. A few stone vases were occasionally placed in the shaft, and in one tomb a great number had been laid on the steps of the stair. The same arrangement was found by Garstang in a great tomb at Bêt Khallaf.

'The portcullis consisted of a large flat block of stone with rounded edges, sometimes as much as 3 mètres long and 1·5 mètres wide, which fitted into a groove cut in the rock. It must have been lowered before the mastaba was built and chocked up so that its base was above the door of the chamber. Ropes were used to aid in lowering it; the channels cut by them were observed in one stone.

'The chamber opened either on the south or west, very rarely the north, never on the east.

'It was generally a small, rudely-cut cave, too small to hold a body laid at full length; this small rough chamber was the general rule, but the larger tombs have a series of chambers of a somewhat elaborate plan.

'On passing the portcullis in these we find ourselves in a broad passage, from which three or four chambers, probably magazines, open on each side.

'A wide doorway at the end leads to a continuation of the passage, and this to further chambers, in which there is some variety of plan; but two features are constant. To the right—that is, to the S.W.—is the actual burial chamber with remains of a single skeleton; in the S.-E. corner is a feature new in Egyptian tombs, and, surely, in any other tombs—viz., a dummy latrine; north of this, in two cases, was a narrow chamber with rude basins carved in the floor—probably meant for a bathroom. The provision for the dead was evidently more thoughtful and complete than in later ages.

'In all these underground chambers the antiquities found were somewhat disappointing. It is true that we did obtain a great number of bowls and dishes of alabaster, diorite, and other stones—indeed, an embarrassing quantity of them—also ewers and basins of copper, occasionally a wooden piece from a draughtsboard, a box or a bit of ivory inlay, and that the mud-seals on the vases were in three tombs inscribed with Kings' names, thereby giving us our assured dates for the cemetery; but the ancient robbers had very different returns for their labour; there had certainly been quite other classes of monuments of which no sample had survived. All the tombs except the very smallest and poorest had been robbed, and robbed, too, at a very early period: this was clear from the knowledge shown by the robbers of the construction, and the skill with which they penetrated to the burial chamber with a minimum of labour. Sometimes the earth inside the chamber had been passed through a sieve: this shows that the second robber had found some gold beads left behind by the first; he (the first one) would not need a sieve—he found the coffin and all the furniture lying clear.

'We assume that there was a coffin in all cases—indeed, fragments were often found, but complete coffins remained in four tombs only, and these four of the poorest.

'They are short, with panelled sides and arched square-ended lid:

two niches are made in the east side. In one coffin, the east side of which alone is here shown, the central panels are covered with a series of slabs; these are rounded at the ends and do not, as one would expect, butt against or mortise into the uprights; this suggests that they are in imitation of a door.' [Similar coffins were subsequently found by Professor Flinders Petrie in a contemporary cemetery *on the opposite* bank of the river.]

'When the east side of the coffin is taken away the body appears, sharply contrasted, with head to the north and face east. The limbs are swathed in linen bands, and masses of linen folded together lie above the body. There was some little evidence of an attempt at mummification, but no flesh remained on the bones; those of the arm lay free inside a wide cylinder of wrappings, which retained the shape of the limb. The preservation of these coffins and bodies was partial; some of the wood was quite sound, other pieces could not be moved. So of the cloth; some had been eaten by white ants, but some was in admirable preservation.

'About fifty skeletons and parts of skeletons were found in fair condition, and these, happily, owing to the visit of Professor Elliot Smith, could be carefully examined, some of them before they had been touched.

'In one only of all these four hundred tombs have paintings been found, but this is of very considerable interest, and the paintings are so extensive that our time for a whole season has been mainly occupied in copying them. This is the tomb of Hesy.

'The panels of Hesy have been, for more than forty years, in the Museum; they were brought there by Mariette, who discovered them and attributed them, correctly, to the Third Dynasty.'

These quotations from Mr. Quibell's report will make it clear that we are dealing with the remains of the very people who were responsible for technical inventions of far-reaching importance in the history, not merely of Egyptian craftsmanship, but of that of the whole world. This series of tombs reveals the stages in the acquisition of the means of cutting out extensive rock tombs; and it is a matter of considerable significance to determine the precise racial characteristics of the people who invented and were the first to practise these arts and crafts which were destined to exert so profound an influence on the world's culture.

The crucial importance of the human remains buried in these tombs depends upon the fact that the earliest bodies hitherto found in Lower Egypt (exclusive of those brought to light at Turah in the winter of 1909-1910 by Professor Hermann Junker, and described by Dr. Derry, to which reference will be made later) belonged to a later period—Fourth to Sixth Dynasties—and revealed undoubted evidence of considerable alien admixture, such as does not occur, except in rare sporadic instances, in the earlier remains from Upper Egypt. The problem for solution was the determination of when and how this process of racial admixture began.

The contemporary and earlier material found by Professor Junker upon the opposite (east) bank of the river, and a little further north,

was in a very bad state of preservation, and no adequate photographic record was obtained to permit of exact comparisons with other collections. But Dr. Derry's report, which seems to suggest that the alien element in these poorer graves did not become certainly appreciable until the time of the Third Dynasty, served to add to the interest of Mr. Quibell's material, and to make it more than ever desirable to secure and preserve a collection of such crucial importance for the investigation of the problems of Egypt's anthropological history.

The chief difficulty that faced me was how satisfactorily to deal with a collection of most fragile bones, a large proportion of which were certain to become damaged, more or less severely, during transport. As there was no anthropologist on the spot to measure and make descriptive notes on the material, it was proposed to employ experts to photograph each skull, and other important bones, before they were treated with size, or other strengthening agent, in preparation for transport to England.

But, while preparations were being made for carrying out this scheme, most of the difficulties were removed by the fact that the Egyptian Government requested me to go out to Egypt in connection with the work of the Archæological Survey of Nubia, and it thus became possible to visit Mr. Quibell's excavations in person, to examine and measure all the material on the spot, to supervise the work of photographing and packing it for transmission to England. It was possible to do so much in the short time at my disposal, because Mr. Quibell and his trained workmen afforded every help, and Mr. Cecil M. Firth and his native photographic assistant, Mahmud Shaduf, of the Nubian Archæological Survey, volunteered to help. Mr. Firth took about a hundred and thirty photographs of the material. Every help was also given by the Egyptian Survey Department in the loan of instruments and other apparatus. Furthermore, the authorities at the Museum of the Royal College of Surgeons in London offered to take charge of and repair the material on its arrival, and to grant me every facility for its investigation.

Full notes and photographs were obtained of all human material rescued by Mr. Quibell, consisting of the remains of thirty-nine individuals of the Second and Third Dynasties, most of which is now safely housed in the Royal College of Surgeons' Museum. At the outset it may be stated that the material closely resembles the human remains of the Pyramid Age found in neighbouring sites of a somewhat later date. There are quite definite evidences of some racial influence alien to the Proto-Egyptian race; but the difficult problem is raised as to how much of the contrast in the features of the two populations—Upper Egyptian and Lower Egyptian at the Second and Third Dynastic Periods—is due to admixture and blending; and how much, if any, is due to the specialisation in type of the Delta portion of the Proto-Egyptian people.

The investigation also revealed some suggestion of attempts at mummification as early as the Second Dynasty—a fact of some interest, as the earliest undoubted case of mummification is referred to the Fourth or Fifth Dynasty (more probably the latter), and no

evidence has been obtained before of attempted mummification of a body which was not buried in the fully extended position.

While in Egypt I took the opportunity of comparing the Saqqara skulls directly with the type collection of Predynastic skulls in the Anatomical Museum of the Cairo School of Medicine, and also with skulls of the Fourth and Fifth Dynasties at Dr. George Reisner's excavations (for Harvard University and Boston Museum) at the Giza Pyramids.

For convenience of comparison I have followed the plan and used the notation explained in the Report on the Archæological Survey of Nubia (1910), vol. ii., p. 40.

Detailed Statement of the Results of Examination of the Human Remains.

2102 F.[3] Man about forty-five years of age, with well-defined alien traits.[4] Buried in a small mastaba with degraded stair placed alongside a big mastaba. A very big, broad, full ovoid calvaria, with large bregmatic bone and squarish orbits, and narrow high-bridged nose. The rest of the face and mandible are missing (that is, were not saved by Mr. Quibell). L. (maximum length of cranium in millimètres) 205, B (maximum breadth of cranium) 146, F.B. (minimal frontal breadth) 98, H. 135, L.O. 38 × 34.

2104 G. A man with a short and very perfect, well-filled ovoid skull, which does not conform to the Egyptian type; rounded orbits; long narrow nose; jaw of distinctly alien type. L. 176, B. 139, H. 137 (approximately), F.B. 90, T.F. 119, U.F. 73, Biz. 122, Interorb. 21, N. 50 × 23, R.O. 39 × 35, L.O. 36 × 34.

2104 J. A characteristic example of the type of skull (male) alien to Egypt, which was found at Giza and also at the Biga Cemetery at Nubia. It has large, obliquely placed, squarish orbits; prominent narrow-bridged nose, with very projecting sharp margins and long nasal spine; a broad face with the zygomatic arches curved strongly outward; a jaw with a wide chin; and a ramus which is narrow, moderately high, and has a big coronoid process. The skull is a short, broad, full ovoid; there is a straight line of brow and nose; very deep conceptaculæ cerebelli, associated with manifestation of an occipital vertebra. L. 174, B. 134, F.B. 93, H. 136, Biz. 130, T.F. 119, U.F. 71, C.B. 99, F.B. 91, Interorb. 22·5, R.O. 37 × 37, L.O. 37·5 × 36, N. 51·5 × 21·5, Big. 102·5. Femur, rough estimate of length, 486. One molar is carious, and there is widespread but slight periostitis of the leg-bones and pelvis. The pelvis and leg-bones are very big and massive.

2104 N.W. Woman, probably about twenty-eight years of age. The skull is a broad, flat ovoid (or beloid), with markedly sloping forehead, the profile passing without break into the nose ('Greek

[3] Distinguishing number of the grave in Mr. Quibell's Archæological Report.

[4] In using the term 'alien traits' I refer to features which are foreign to the Proto-Egyptian people as well as to the Brown Race in general. In most cases—as for example this instance—these foreign features, such as 'a very big, broad, full ovoid calvaria,' 'squarish orbits,' and 'narrow high-bridged nose' are distinctive of the Armenoid population of Western Asia.

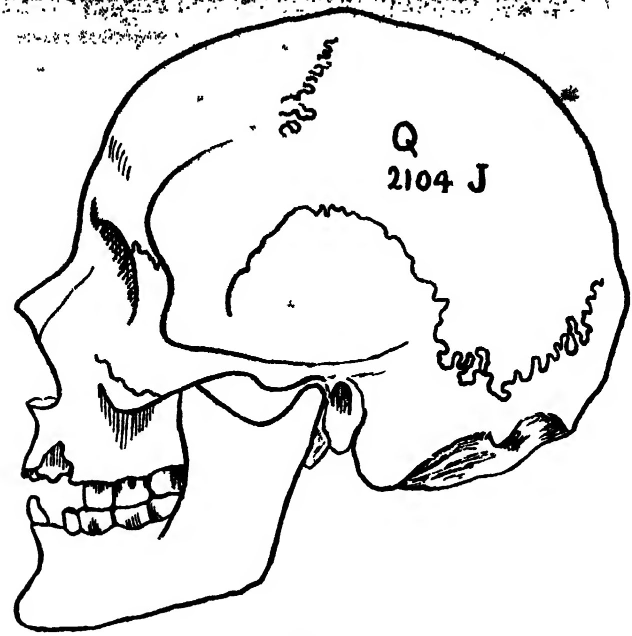


FIG. 1.

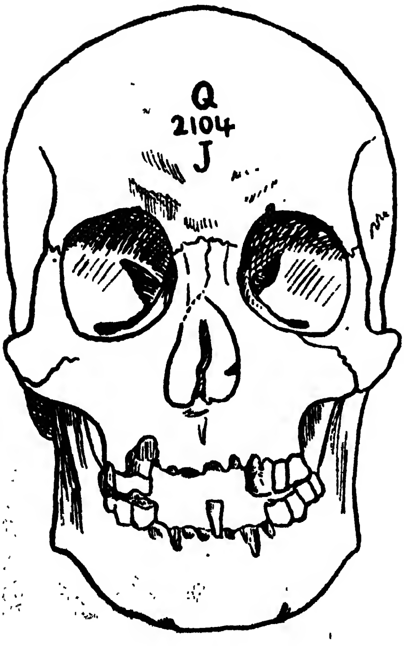


FIG. 2.

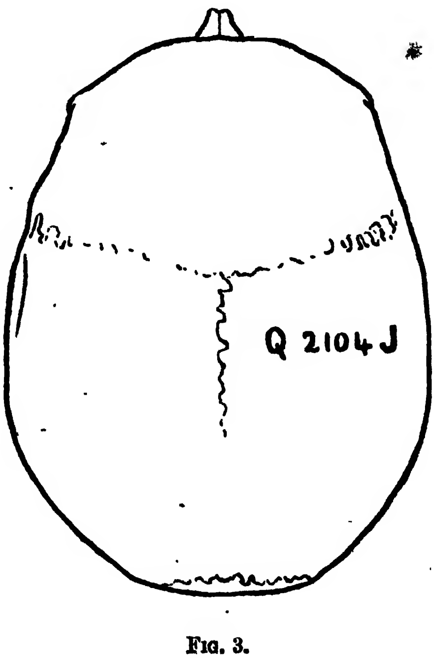


FIG. 3.

profile'); square orbits with rounded angles; nose moderately broad and not very prominent, but the nasal spine is large. In most respects the mandible conforms to the Proto-Egyptian type, but the ramus shows a tendency towards the form distinctive of the Biga population (see 'Report of the Archæological Survey of Nubia,' 1907-1908, vol. ii.). The teeth are perfectly healthy. The femur is small and slender, with slight flattening of the upper part of the shaft. The length of the right femur is 407, and the diameter of its head 38. L. 178·5, B. 138, F.B. 93, H. 132, Biz. 122, T.F. 120, U.F. 76, C.B. 102, F.B. 98, Interorb. 24·5, R.O. 39×34, L.O. 36×34·5, N. 55×27, Big. 87, Sym. 36.

2104 H.E. This is a man about twenty or twenty-one years of age, with a curious blending of the features seen in the skeletons of the man 2104 J. and the woman 2104 N.W., having the cranial features of the former and the facial traits of the latter. The skull is a moderately broad, well-filled ovoid, with a sloping forehead and a profile like 2104 N.W. The nose also resembles that of the latter, but is also curiously like that found in the Nubian people at the time of the Middle Kingdom. Its lower margins are rounded. The orbits are not quite so square as those of N.W., being almost elliptical and oblique. The teeth are perfectly healthy and unworn. The large size of the canines and incisors has produced slight prognathism. The left tibia is 306 in length; its epiphyses are just consolidating. L. 181·5, B. 141, F.B. 97, H. 138·5, Biz. 131, T.F. 120, U.F. 73, Interorb. 27, R.O. 40×33, L.O. 38×33, N. 52·5×26, Big. 86, Sym. 35.

2162. An elderly man with the coronal, sagittal, and lambdoid sutures almost completely closed. The teeth are well worn, but healthy, excepting for a 'perforation abscess'[5] at the root of the lower right first molar. There is, however, a considerable amount of tartar deposit on the teeth. The cranium is a big ovoid or beloid, with prominent superciliary ridges; small, flat, horizontal orbits; small, narrow, high-bridged, sharp-edged nose; a wide jaw, with broad chin, and a moderate ramus of alien form, with out-splayed angles. There is evidence of severe arthritis in the left temporo-mandibular joint. The face conforms to a type which is often seen in the Dynastic Egyptian. L. 193, B. 139, H. 136, F.B. 91, Big. 105, Sig. 52, T.F. 113, U.F. 69, Biz. 134, N. 54×25, Interorb. 26, L.O. 38×29, R.O. 37×30.

2116 N. This skeleton is probably a woman's. It conforms to the Proto-Egyptian type, the mandible being quite typical, and the skull a long ellipsoid, which is well filled. None of the cranial sutures show any sign of closing, although the teeth are moderately worn and encrusted with deposits of tartar. L. 181, B. 129, F.B. 93.

2146. A middle-aged or elderly man, with a full ovoid or beloid skull, with flattened occiput, somewhat rounded orbits, and moderately prominent nose. The coronal, sagittal, and lambdoid sutures are closing, and the teeth are worn down, and there are

[5] By this term I refer to an alveolar abscess, which is not due to dental ·oad, but originates by infection through the pulp cavity of a tooth, which has distinosed by excessive wearing-down.

several 'perforation abscesses.' There is thinning of the left parietal bone. L. 183, B. 139, H. 146, F.B. 93, U.F. 72, Biz. 130, N. 53·5×25, Interorb. 24, L.O. 38×33, R.O. 38×33.

2152. Middle-aged man, whose coronal and sagittal sutures are beginning to close. The teeth are well worn down, and there are four 'perforation abscesses,' that associated with the upper left second molar opening by a large perforation into the maxillary antrum. The jaw is a big, heavily built ovoid, with well-marked muscular impressions and prominent superciliary ridges. The orbits are flat and horizontal, the nose is narrow with a prominent high-bridged root. L. 188, B. 138, H. 138, F.B. 100, U.F. 69, Biz. 135, N. 49×24·5, Interorb. 24, L.O. 40×32, R.O. 40×33.

2170. A man whose coronal suture is beginning to close, and whose perfectly healthy teeth are only slightly worn. The skull is a big, well-filled ovoid, with sloping forehead and moderate superciliary ridges. The face is short and broad, with small, narrow nose and very flat orbits. The jaw is heavily built, but its form is Proto-Egyptian. L. 187, B. 141, F.B. 95, H. 138, Big. 131, T.F. 110, U.F. 67, Interorb. 25, R.O. 40×32, R.O. 40×33.

2170. A man whose coronal suture is beginning to close, and whose perfectly healthy teeth are only slightly worn. The skull is a big, well-filled ovoid, with sloping forehead and moderate superciliary ridges. The face is short and broad, with small, narrow nose and very flat orbits. The jaw is heavily built, but its form is Proto-Egyptian. L. 187, B. 141, F.B. 95, H. 138, Big. 131, T.F. 110, U.F. 67, Interorb. 25, R.O. 40×30·5, L.O. 38×30·5, N. 53×24.

2173 D. This is a child of nine or ten years, with a typical Proto-Egyptian pentagonoid skull.

2172 B. This is a woman of twenty years, or perhaps a little more, with a small head of Proto-Egyptian type, and well filled pentagono-ovoid form; the nose has a small horizontal, elliptical, flattened bridge; small mandible, with a very pointed chin: the zygomatic arches are laterally compressed. The teeth are in excellent condition and practically unworn. L. 178, B. 128, F.B. 85, H. 129, Biz. 116 (estimated), T.F. 111, U.F. 68, C.B. 98, F.B. 94, Interorb. 24, R.O. 38×27, L.O. 35×28, N. 46×24·5, Big. 82, Sym. 35, Sig. 45.

2172 E.B. A woman with very perfect, small, well-filled ovoid or ellipsoid cranium. The face might be Proto-Egyptian, but the large orbits and prominent-spined nose suggest alien affinities. The coronal suture is beginning to close. L. 173, B. 130, F.B. 90, H. 138·5, Biz. 121, T.F. 102, Interorb. 20, R.O. 37×32, L.O. 38×32, N. 48×23.

2172 *α* (? or *β*). This is a man with teeth moderately worn, but quite healthy. Sutures all open. Long pentagonoid cranium with a markedly *bombé* occipital. Prominent superciliary ridges thickening whole upper edge of orbits meet across the mid-line, overhanging the depressed and flattened root of the nose. Orbits flattened; nose wide; typical Proto-Egyptian jaw, with pointed chin and characteristic ramus. L. 194, B. 136·5, H. 141, F. 95, T.F. 107, U.F. 66, Biz. 130, N. 49×30, L.O. 38×30, R.O. 39×29, Interorb. 23·5.

2173. A woman about twenty-one years of age. Teeth healthy.

Typical Proto-Egyptian pentagonoid skull, with small, broad, flat-bridged nose (nasals fused), not separated by any depression from the frontal; oblique orbits, and typical high ramus and coronoid process of the alien type of jaw. L. 173, B. 133, H. 133, F. 92, T.F. 110, U.F. 67, N. 47 × 23·5, Interorb. 24, R.O. smashed.

2173 A. This is a woman with teeth well worn; left upper molars carious, abscesses at all upper molars. Temporal part of coronal suture closed, as well as the whole sagittal and part of lambdoid. Big broad ovoid head, with senile thinning commencing. Broad face with out-curved zygomatic arches and out-splayed angles of jaw. Long, very narrow nose, with prominent spine, but not very high bridge. Large square orbits, with deficient lateral walls. Left femur is severely affected by osteomyelitis, according to Professor Ferguson, of Cairo, who had taken the bone before I arrived at Saqqara. Large inflammatory excavation in front of right sacro-iliac joint. L. 183, B. 137, F. 96·5, H. 135. Biz. 133, T.F. 125, U.F. 80, Interorb. 23, R.O. 39 × 36·5, L.O. 40 × 37, N. 55 × 23, Big. 106.

2173 D. A woman's skull, almost edentulous, but all the sutures are still open. A broad, flat, beloid cranium associated with a small infantile face. L. 175, B. 138, F.B. 90, H. 117, Biz. 119, T.F. 101, U.F. 69, R.O. 37 × 30, L.O. 36 × 31, N. 52 × 22.

2175. A man with all upper incisors and right canine teeth gone, probably the result of some alveolar disease, leaving now a large hole about 27 mm. in diameter. The three principal sutures are closed. Has a large, lofty, well-filled ovoid skull. Face very long, narrow and ovoid, with Proto-Egyptian type of orbits; but small, narrow, high-bridged, sharp-margined nose. Pointed jaw with a high ramus, set at so oblique an angle that the sigmoid height cannot be measured. L. 185·5, B. 144, F.B. 96, H. 140, Biz. 131, T.F. 130, U.F. 73 (estimated), Interorb. 21, R.O. 41 × 32, L.O. 40 × 32, N. 50 × 24.

2262. A woman with a perfect set of healthy, almost unworn teeth; temporal part of coronal suture closed. A big broad pentagonoid skull with large alien jaw and rounded orbits. L. 189, B. 141, F.B. 95, H. 131, Biz. 122, T.F. 119, U.F. 72, Interorb. 24, R.O. 37 × 33, L.O. 36 × 33·5, N. 49 × 24.

This individual exhibits signs suggestive of some form of mummification having been attempted. If so, it is the earliest authentic evidence of such a practice. The skeleton was found completely invested in a large series of bandages—more than sixteen layers still intact, and probably at least as many more destroyed—ten layers of fine bandage (warp seventeen and woof forty-eight threads to the centimètre), then six layers somewhat coarser cloth, and next to the body a series of badly corroded, very irregularly woven cloth, much coarser (warp six and woof fourteen per centimètre) than the intermediate and outer layers. Each leg was wrapped separately, and there was a large pad on the perineum. The bandages were broad sheets of linen rather than the usual narrow bandages. The body was flexed, as was usual at this period.

In the wide interval between the bandages and the bones there was a large mass of extremely corroded linen, whereas the intermediate

and superficial layers of cloth were quite well preserved and free from corrosion, except along a line where the cloth was corroded to represent the rima pudendi—a fact of great interest when it is recalled that in the Fifth and probably the Fourth Dynasties it was the custom to fashion (in the case of male mummies) an artificial phallus.

The corrosion is presumptive evidence that some material (probably crude natron) was applied to the surface of the body with a view to its preservation. If so, this is the earliest body with unequivocal evidence of an attempt artificially to preserve or prevent decomposition in the soft tissues.

2262 N. (?) Woman aged twenty years of age. The teeth are healthy and almost unworn. Cranial sutures all open. Small infantile face of characteristic Proto-Egyptian type. Broad pentagonoid

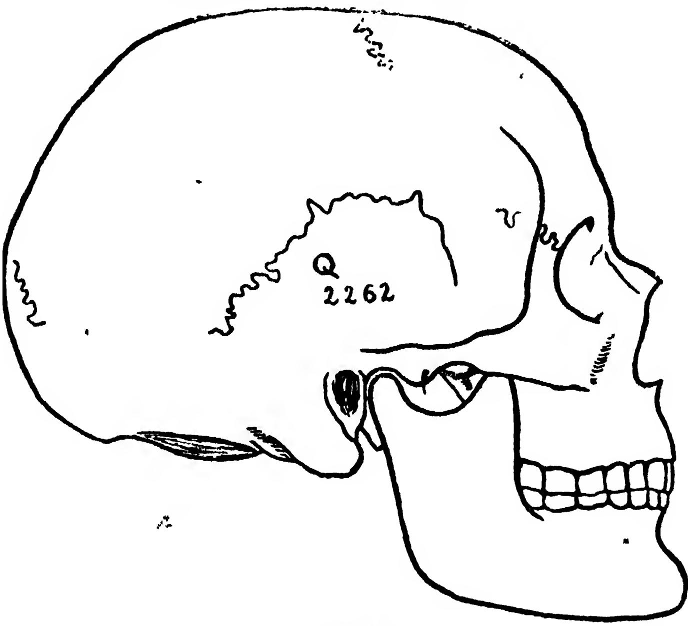


FIG. 4.

cranium and flat orbits. L. 185, B. 142, F.B. 83, H. 136, Biz. 124, T.F. 105, U.F. 63, Interorb. 21·5, R.O. 39·5×30, L.O. 37×30, N. 48×23.

2262 B.N. A small tomb containing a man aged about forty years. Teeth extremely worn; right lower molar carious; severe alveolar abscesses in upper jaw; only a few stumps left. Typical Proto-Egyptian pentagonoides, shading into ovoides. Low, very slightly oblique orbits; narrow nose with high bridge, very sharp margin and prominent spine. Semitic curve of nasal bones. Mandible with widely splayed angles. The face as a whole, while Proto-Egyptian in type, has a suggestion of the criminal Blemmye type in jaw, nose, and orbits—? a Sinaitic Arab. Three lower incisors (two right and one left removed), left zygomatic arch fractured, and rejoined with inward

bend. L. 189, B. 135, F.B. 97·5, H. 141, Biz. 130, T.F. 110, U.F. 70, O.B. 105, F.B. 93, Interorb. 23, R.O. 38·5×30·5, L.O. 39·5×31, N. 50×23, P. 53×37, Big. 108, H.S. 28.

2262 J.N. A man of about twenty years of age. Basilar recently closed. Teeth healthy and only slightly worn. Perfect Proto-Egyptian type. Long ovoid, fairly broad. L. 183, B. 137·5, H. 135, F. 89, U.F. 69, Biz. 120, N. 50×23, Interorb. 22, L.O. 36×29 (flat, horizontal, oblong), R.O. 38×30.

2196. This is a man whose coronal is beginning to close. Very full broad ovoid; large squarish orbits; very narrow, long, high-bridged nose; no jaw. L. 188, B. 137, H. 145, F. 91, U.F. 75, N. 55×23, Biz. 130 (curved out), Interorb. 20, L.O. 37×33, R.O. 37·5×31·5.

2187. A woman of about twenty-five years, with teeth quite healthy. Flattened beloid skull, with Proto-Egyptian jaw and horizontal flattened orbits. Small Proto-Egyptian nose and slight prognathism. L. 171, B. 140, H. 132, F. 90, Interorb. 22, L.O. 37·5×29, R.O. 38×29, N. 44×23, Biz. 120, U.F. 62·5, T.F. 105.

2256 N. A man almost edentulous, seven stumps flush with gum. Coronal, sagittal, and lambdoid closed. Big, well-filled ovoid head; oblique squarish orbits, and narrow prominent nose of alien type. L. 186, B. 138, H. 134, F. 104, U.F. 73, Biz. 132 (well curved out), Interorb. 24, L.O. 40×32, R.O. 37×33 (right occiput much more prominent), N. 54×24.

2256 S. A child of thirteen or fourteen years. Flat beloid skull *175×133, H. 133.* Small elliptical horizontal orbits. Very narrow, sharp-edged, prominent nose.

2256 S. (2nd.) Child about seven years old. Long, narrow, pentagonoid skull. L. 176, B. 127.

2191. Woman. Coronal and sagittal sutures beginning to close. Metopic suture present. Teeth moderately worn and perfectly healthy, with slight tartar. Slender beloid skull. Fronto-nasal profile an unbroken line, sharp-edged nose of type suggestive of Giza (that is, from the necropolis of the Great Pyramids) aliens. L. 174, B. 130, H. 124, U.F. 65, N. 48×24, L.O. 39×31, F. 87·5, Interorb. 22.

No. ? A man aged fifty years; principal sutures closing, but teeth only slightly worn and quite healthy. Large beloid skull, but face of Proto-Egyptian type, with small pointed mandible. Nose probably of bulbous type (like that of King Mycerinus, as displayed in his statues). L. 189, B. 144, F. 97, H. 141, Biz. 129, T.F. 73, Interorb. 26, R.O. 40×32, L. 39×32, N. 50×28, Femur R. 468, head 45.

No. ? Man with small, regular, well-worn, perfectly healthy teeth. Temporal part of coronal suture closed. A somewhat effeminate skull with typical small-featured Proto-Egyptian face, but well-filled ovoid cranium. L. 179, B. 138, F. 96, H. 137, Biz. 123, T.F. 108, U.F. 70, Interorb. 25, R.O. 36·5×31, L.O. 36×30, N. 49·5×24.

2307. A skeleton, probably female, obtained from a large mastaba, but not certain. Coronal, lambdoid, and sagittal sutures closed. Well-filled ovoid skull. L. 185, B. 137, H. 126, F. 100.

2311 B. A woman forty-five years of age. Large, well-filled,

broad ovoid, almost ellipsoid cranium. Face of Proto-Egyptian type; moderately large, almost horizontal orbits; moderate nose; typical pointed Proto-Egyptian jaw; low ramus, with small coronoid. Vertical forehead, passing without interruption into line of nose. Femur R. 413, head 40. Femur small, with no pronounced features, slenderly built. Diameter of head, 40 mm. L. 181, B. 137, F. 93, H. 139, Biz. 127, T.F. 116, U.F. 73, C.B. 99, F.B. 92, Interorb. 24, R.O. 38 × 31, L.O. 40 × 31, N. 50 × 24, Big. 84, Sym. 30, Sig. 47, Cir. 510.

2313 W. A man with healthy but well-worn teeth; left upper

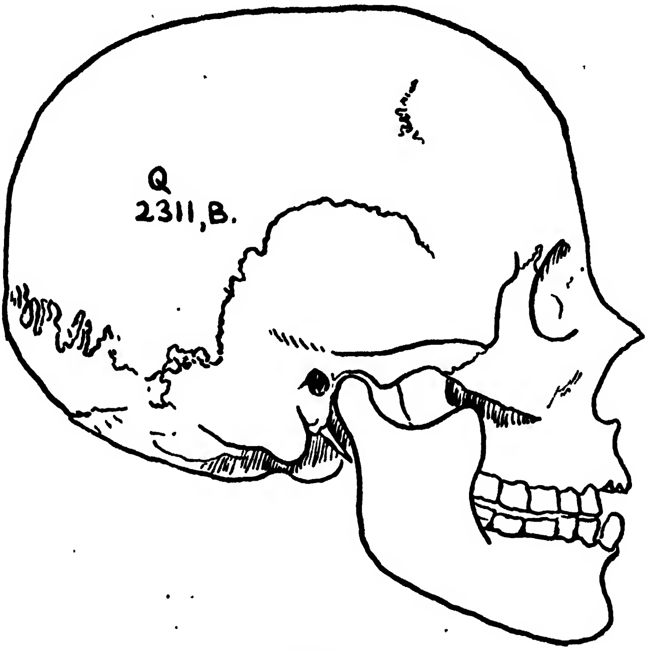


FIG. 5.

incisor missing and a curiously regular bevelled V-shaped hole in its place. Coronal and sagittal sutures closing. A big, high, ovoid cranium, with very narrow, high-bridged, prominent, sharp-margined, prominent-spined nose. Large squarish orbits; jaw with moderate ramus; beard on chin; race certainly alien. L. 186, B. 143, F. 92, H. 138, Biz. 130, T.F. 124, U.F. 76, Interorb. 21, R.O. 40×34, L.O. 39×35, N. 55×23.

2314 C. Man. Small pentagonoid skull of Proto-Egyptian type, cranium greatly thickened (parietal, 11 mm.).

2315 N.E. A man's skull, with coronal suture just beginning to close. Ovoid head with prominent superciliary margin; a small, narrow, sharp-margined, prominent-spined nose, otherwise typical small-featured Proto-Egyptian. L. 180, B. 139·5, F. 90, H. 143, Biz. 125, T.F. 119, U.F. 72, Interorb. 21·5, R.O. 39×31, L.O. 38 × 32, N. 50 × 25. Some tartar on the teeth, which are well worn.

An abscess, starting from the infection of the pulp cavity of the worn left upper molars, has eroded large holes in palate and into maxillary antrum.

2316. Probably a female about thirty-five years. Cranium is a well-filled ovoid, with flattened occiput, with fairly broad, sloping forehead. Moderately large squarish orbits, and small, narrow, and not very prominent nose. Teeth perfectly regular, and only very slightly worn. Mandible with somewhat curved body, and a narrow ramus, but not very high. In the temporal fossa there is a very marked prominence in the postero-lateral corner of the frontal. On the left side series of four lumbar vertebræ and the sacrum probably belonging to this body ankylosed by severe inflammatory process, which also affects the sacro-iliac joints, although there is no fusion of the bones in these joints. L. 174, B. 134, F. 96, H. 130, Biz. 123, T.F. 111, U.F. 70, C.B. 97, F.B. 95, Interorb. 26, R.O. 40 × 33, L.O. 39·5 × 34, N. 50 × 24·5.

2323 C. Woman with temporal suture closing and parietal thinning becoming apparent. Thick mass of tartar on teeth. Alveolar abscesses around upper molars. Very small head with typical Proto-Egyptian face, but rather well-filled ovoid cranium. L. 167, B. 129, F. 86, H. 129·5, Biz. 115, T.F. 105, U.F. 65, Interorb. 20, R.O. 35 × 30, L.O. 35 × 30, N. 49 × 23.

2338. Probably a man with very effeminate skull. The femur suggests masculine sex. Coronal suture closing. Large tartar deposits on the teeth; alveolar abscesses at the two lower molars on both sides. Typical Proto-Egyptian pentagonoid skull; large square orbits, but otherwise characteristic Proto-Egyptian face with suggestion of negroid influence. Very slender humeri, the right coronoid fossa perforated, anterior lamella only of left gone. Femur R. 443, head 44, L. 184, B. 132, F. 91, H. 134, Biz. 123, T.F. 118, U.F. 69·5, C.B. 95, F.B. 93, Interorb. 24, R.O. 39×36, L.O. 39×36, N. 50×23·5.

2344 A. Woman about forty years of age. Typical Predynastic narrow pentagonoid skull. Orbits were small, horizontal, and elliptical. Mandible was missing. Long and very slender femur with no outstanding peculiarities. Diameter of head 38. Femur R. 440, oblique. L. 175, B. 131, F. 83, H. 135, Biz. 120, U.F. 69, Interorb. 24, R.O. 35×31·5, L.O. 35×31·5, N. 40×24.

2347 C. A woman's cranium of Proto-Egyptian type, with sutures open. Facial skeleton missing. L. 180, B. 134, H. 131, F. 91.

2358. A woman with perfectly healthy, only slightly worn teeth. Temporal part of coronal suture closing. Perfect ovoid skull, with sloping forehead and uninterrupted line of forehead and nose. Rounded orbits and sharp-edged narrow nose of somewhat alien appearance. L. 180, H. 135, B. 137·5, F. 89, U.F. 67, Biz. 120, N. 49 × 23, Interorb. 20, L.O. 37 × 33, R.O. 38 × 33.

Skull found on stair north of 2376. Man. Teeth healthy and only slightly worn. Cranial sutures all open. Flattened beloid skull, with sloping forehead; jaw with broad chin and moderate ramus. Femur R. 445, head 42. Tibia curved and platycnemic. L. 182, B. 140, F. 97, H. 130.

2416. A man with coronal suture beginning to close and sagittal half-closed. Big broad pentagonoid skull, the face being Dynastic-Egyptian in type, with Proto-Egyptian jaw. Three lower incisors removed at some time. L. 187, B. 141, F. 99, H. 139, T.F. 120, U.F. 74, Biz. 137 (established), Interorb. 27, R.O. 38 × 31, L.O. smashed, N. 52 × 20.

2433. Sex uncertain. Temporal part of coronal suture closed. Mandible healthy and well worn. Left upper first molar and first premolar alveolar abscesses due to infection through the pulp cavities exposed by the wearing down of the teeth. Large abscess destroyed alveolus from second lower right molar to the premolars (inclusive). Small well-filled ovoid cranium. The nose has a somewhat flattened bridge, the jaw being rather a pronounced feature, typically Lower Egyptian. L. 171, B. 132, F. 90, H. 131·5, Biz. 128, T.F. 106, U.F. 67, C.B. 98, F.B. 94, Interorb. 22, R.O. 39 × 33, L.O. 37 × 31, N. 50 × 23 (moderately large orbits, not very oblique), Big. 86, Sym. 27, Sig. 52 (moderate outward curve of zygomatic processes).

The Significance of these Data.

In discussing the facts thus set forth I cannot refrain from expressing regret that it was not possible to examine each skeleton *in situ* in the tomb. For in removing human remains from tombs, not only does the material suffer considerable damage, but a great deal of the most valuable kind of evidence is destroyed. In this particular instance the loss of this opportunity is particularly regretted, because I feel sure important facts bearing upon the early practice of mummification might have been recovered.

In making these remarks I am not unmindful of the fact that Mr. Quibell removed the material from the tombs into his workroom with the object of facilitating my work and enabling me to do as much as possible in the limited time which I was able to spend upon this work at Saqqara.

Apart from supplying what is perhaps the earliest evidence of attempts at mummification (see the account of No. 2262 above), this group of remains has also provided the earliest known instances of symmetrical thinning of the parietal bones not due to senile changes. That this parietal atrophy was not due to old age is quite certain, because the best-marked case occurred in the skull of a young woman (No. 2323 C) who could not have been much more than thirty years of age. This is interesting in view of the fact that such parietal thinning has not hitherto been known to occur at so early a period, although it became exceedingly common in the Pyramid Age, two Dynasties later. Its causation seems to be associated with the habit of constantly wearing heavy wigs, which by pressure affect the blood supply of the parietal bones.[6]

Another interesting feature of the material discussed in this report is the rarity of dental caries, which became so common and wrought such appalling havoc in the successors of these people of Memphis a

[6] Elliot Smith, 'The Causation of the Symmetrical Thinning of the Parietal Bones in Ancient Egyptians,' *Journal of Anatomy and Physiology*, vol. xli., 1907.

few years later during the Pyramid Age. Alveolar abscesses are common enough, but they are not, as a rule, the result of dental caries, as I have explained above.

The contrast presented by this collection of human remains to hose of the Proto-Egyptian population of the Predynastic period is o profound, and the alien features so widely diffused amongst them, hat a fundamental problem is raised for discussion. This question is o large that I propose specially to consider its bearings in a separate ommunication to the Association.

The intimate blending of this Egyptian population with a people foreign type and origin at so early a period as the Second and Third ynasties points to the fact that we have to deal, not with a recent admixture, but one which must have been taking place for many nerations before the time of the Second Dynasty. But we have no idence to indicate whether the Western Asiatic element—for there n be no doubt as to the nature of the alien strain—had been percolat- g into the Delta gradually, or came more suddenly in larger volume ssibly as a people already mixed to some extent with Egyptian blood Syria or elsewhere.

The important result emerges from such considerations that the ople who developed the wonderful and precocious civilisation of ypt were not pure Proto-Egyptians. The growth of early Egyptian ilisation no doubt represents the gradual evolution of the ideas and arts and crafts which we know to have had their origin among the dynastic people of Upper Egypt; but their full fruition came only en the contact of peoples of diverse origin in Lower Egypt brought influence of new ideas and new manners of thought—probably a more virile type of intellect—to stimulate and help in the elopment of the Egyptian civilisation.

The Human Remains of the Hyksos Period found in the Southern Part of the Kerma Basin (Sudan).

At the end of 1913 I received from Professor George A. Reisner, , working on behalf of Harvard University and the Boston eum, had excavated a site at the south of the Kerma Basin, in Dongola Province, a series of skeletons of the Hyksos Period. e bones were sent to me for examination, with the consent of the æological Committee of the Sudan Government and the approval e Governor-General, Sir Reginald Wingate, whose interest in the opology of the Sudan is well known.

s only a part of the material has yet been sent to me, and as Reisner has not yet communicated the details of the archæological nce, it would perhaps be preferable if I withhold my report until year.

may say that the tombs of the wealthier people contained the ns of typical Egyptians, such as we know to have lived in the id during the times of the New Empire; while the other tombs ned skeletons of Proto-Egyptian and Middle Nubian (C group) Although slight negroid traits are common, there is a sur- g absence of the more obtrusive negro features.

Artificial Islands in the Lochs of the Highlands of Scotland.—Fourth Report of the Committee, consisting of Professor Boyd Dawkins (*Chairman*), Mr. A. J. B. Wace (*Secretary*), *and* Professors T. H. Bryce, J. L. Myres, *and* W. Ridgeway.

Since, owing to the meeting of the Association in Australia this year, reports have to be sent in at a much earlier date than usual, the Committee have so far little to record. The Rev. F. O. Blundell, the Committee's correspondent at Fort Augustus, continues to collect and tabulate information. He desires to thank the Committee for their assistance and for their encouragement in his investigations of a subject which, though full of interest, presents many difficulties that can scarcely be realised by those who have not taken part in the work.

By the courtesy of the Society of Antiquaries of Scotland, fifty reprints of the paper read before that Society, containing numerous illustrations, have been circulated amongst the correspondents of this Committee, and this has again stimulated interest in the subject. The Paper, which was compiled largely from the replies to the British Association inquiry, was printed in full in the 'Transactions' of the Society, and elicited numerous letters of congratulation on the results obtained by the Association. Mr. Gilbert Goudie, F.S.A.Scot., writes amongst others:—'May I be allowed to add that I have been much impressed by your paper on Artificial Islands in the "Proceedings of the Society of Antiquaries of Scotland"? These I had previously regarded as entirely exceptional and rare, but the numerous instances you adduce go far to show that they were almost the normal idea—quite a new conception which will influence me largely in looking at these things in future.'

One of the main objects of the Committee is to secure a suitable site for excavation. The artificial island in Loch Kinellan was provisionally fixed upon last year for excavation this year. Now Mr. F. C. Diack of Aberdeen has sent photographs and particulars of the 'Island' in the Loch of Leys, Banchory. The loch is now completely dry, and therefore this island is a much more suitable site for excavation than that in Loch Kinellan. The Secretary proposes to visit the site with the Rev. F. O. Blundell in July, and hopes to receive the permission of the proprietor, Sir Thomas Burnett, Bart., of Crathes, for the proposed excavation. It is hoped that the funds at the disposal of the Committee, together with a grant made by the Carnegie Trust to Dr. R. Munro for the excavation of the island in Loch Kinellan, will be sufficient for a preliminary excavation.

The Committee desires to be reappointed and that a grant of 5*l.* should be applied for at the next meeting of the British Association.

It will be necessary for a new Secretary to be appointed—Professor T. H. Bryce is suggested.

Exploration of the Palæolithic Site known as La Cotte de St. Brelade, Jersey, during 1914.—*Report of the Committee, consisting of* Dr. R. R. MARETT (*Chairman*), Dr. A. KEITH, Dr. C. ANDREWS, Dr. A. DUNLOP, Mr. G. DE GRUCHY, Col. R. GARDNER WARTON (*Secretary*), *appointed to excavate a Palæolithic Site in Jersey.*

Scheme of Operations.

THE Committee arranged with Mr. Ernest Daghorn, who had for the three previous years carried out the excavation of this site with signal success, that for the sum of 50*l*. (being the full grant authorised by the British Association) he should supply throughout the months of March and April 1914, viz., for forty-eight working days, the services of three experienced quarrymen, while himself superintending their labours; that he should bear the responsibility for all accidents; and that he should furnish whatever tools or other appliances might be required for the work. The Committee has to thank Mr. Daghorn for having amply fulfilled all that was expected of him. The men worked with a will, and great intelligence was displayed in the execution of orders.

Attention was exclusively directed to the main cave, already partially excavated by the Société Jersiaise in 1911 and 1912. Meanwhile it was hoped that it might be found to extend round the back of the ravine, up to now masked by talus, and so to be continuous with the smaller cave opposite, which Messrs. Marett and de Gruchy uncovered in 1913. Hitherto exploration of the main cave had been confined to the outer or western side, where the roof is somewhat lower and the pile of superincumbent débris consequently less. As the side contiguous with the back of the ravine is approached, the mass overlying the palæolithic floor and reaching up to the roof passes from about twenty-five to some forty feet of thickness; so that for every square foot of floor to be cleared an amount of material weighing approximately a ton has to be removed. It was now decided to tackle this heavier part of the task and, as far as might be possible in the time, to carry the clearing right across the mouth of the cave to whatever might prove to be its inner or eastern limit.

For the first three weeks the attack concentrated on the upper portions of the cave-filling, the extreme top being demolished by a successful piece of blasting which brought down some eighty tons. The ultimate aim being to open up the floor outwards from a line running parallel to the mouth about eighteen feet from it, it was necessary to cut back the higher portions of the detritus to the extent of another ten or twelve feet, so as to provide some sort of slope, and thus minimise the result of sudden downfalls. This was done without revealing either the true back of the cave or the supposed chimney through which the clay and rock-rubbish, other than what is due to roof-collapse, must have descended. It may be noted, however, that a tentative excavation on the further or northern side of the cliff into

which the cave penetrates brought to light a considerable fissure, about twenty feet higher than the level of what is to be seen of the cave-roof; and this may very well turn out to be the upper end of this hypothetical funnel. For the rest, these topmost parts of the cave-filling proved to be absolutely sterile, with the single curious exception that right at the back of the cave, some thirty-five feet above the floor, a piece of bone was noticed to jut out When this was with some difficulty rescued from its rather inaccessible position, it was found to have all the appearance of extreme antiquity, and is probably assignable to *Bos*. Presumably, therefore, it is contemporary with the cave-filling, and came down therewith from above.

It was calculated that it would be just possible with two months' work to carry a clearing about eighteen feet broad right across the mouth of the cave to its eastern side-wall, since its upper and visible portion, distant about thirty feet from the opposite side-wall, showed a perpendicular drop which might be presumed to extend indefinitely downwards. On April 8, however, it was discovered that this wall, along the whole breadth of the eighteen feet in process of clearance, was undercut, at a point about sixteen feet above floor-level, by a further cavity. To judge by the narrow section opened up, there is not less than twelve feet of additional penetration to be reckoned with on this side. Shielded as it is by its lower roof, this annexe would appear to be at once remarkably dry and free from shattering falls of rock. Thus it offers conditions more favourable to the preservation of bone than the high-domed cave on which it borders, and would be an ideal place in which to come upon human remains. This discovery led to a modification of the original plan, the breadth of the clearing being reduced to about ten feet, so as, consistently with thorough exploration of the portion of floor uncovered, to stretch forth a 'feeler' in this tempting direction. Nothing short of a fresh bout of excavation, however, supported by a grant no less substantial than the last, will enable the Committee to cope with this unexpected lateral extension of the main cave; not to speak of the rearward parts of the cavern which are likely to prove more or less prolific also.

In proceeding towards the eastern wall it was at first impossible to note any stratification in the gradually thickening floor owing to the large blocks distributed through it. At about twenty feet, as measured from the western side, there was, for the first time, clear evidence of some sort of stratification. For three feet above floor level there was a bed of thick ashes of a deep black colour. Above for about one foot succeeded an almost completely sterile layer. Then, for another two feet, occurred frequent implements in a layer of brownish clay, interspersed with slight traces of a darker matter. It was at first thought that the implements of the lower layer were rougher, and that, in particular, the typical Mousterian 'point' was absent. Subsequent observation, however, controlled by careful segregation of the finds from each layer, failed to bear out this view, some of the finest points (one of them, however, being worked on both sides, and in this way suggesting an older style of manufacture) being found in the lower bed. Of course a more detailed examination of the products

Acknowledgments.

The Chairman, Dr. R. R. Marett, directed operations from March 21 to April 22, inclusive, the Secretary, Colonel Warton, assuming responsibility for the rest of the time. Nine members of the Oxford University Anthropological Society, including Dr. F. C. S. Schiller and Mr. W. McDougall, F.R.S., took an active part in the work, while there were also many local helpers, most of them members of the Société Jersiaise. Special thanks are due to Mrs. Briard for the use of her car and for her personal assistance in the important matter of transport; to Mrs. Coltart and Miss Bayly for their help both in finding and in dealing with the finds; to Mr. G. de Gruchy, the proprietor of the site, who helped in the actual work of excavation for about a fortnight; to Captain A. H. Coltart (Exeter College), who actively superintended the work during its final stages, and took a leading part in arranging the material at the Museum; to Mr. B. de Chrustchoff (Lincoln College), who for a month inhabited a small cabin upon the site itself, and acted as custodian of the treasure; to Mr. T. B. Kittredge (Exeter College), who was constantly at work for a month, and afforded great assistance in every way; to Mr. Emile Guiton, of the Société Jersiaise, who acted as photographer-in-chief; to Mr. Joseph Sinel, curator of the Museum of the Société Jersiaise, who took efficient steps to secure the preservation of the osteological remains; and last, but not least, to Dr. Smith Woodward and Dr. Andrews, of the British Museum, for the determination of the fauna represented by these remains.

Future Policy.

The Committee wishes to apply to the British Association for a grant of not less than the sum previously given, in order that the work may be continued without delay. It is well-nigh a certainty that a rich store of remains awaits excavation, and, indeed, that it lies exceedingly near to hand, more especially along the eastern side, where the hearth deposits are particularly rich. Any such grant will be devoted entirely to the work of removing the débris. All incidental expenses will be met by local contributions, as in the present case.

The Production of Certified Copies of Hausa Manuscripts.—Report of the Committee, consisting of Mr. E. S. HARTLAND *(Chairman)*, Professor J. L. MYRES *(Secretary)*, Mr. W. CROOKE, *and* Major A. J. N. TREMEARNE.

THE sum of 20*l*., placed at the disposal of the Committee in 1912, has been expended in payment of the printer.

Copies have been presented as follows: To the Committee for Anthropology, Oxford; the Syndicate for Anthropology, Cambridge; the Imperial Institute; the London School of Economics; l'Ecole d'Anthropologie, Paris; the University Library, Berlin; the India Office Library; Exeter College, Oxford; Christ's College, Cambridge; King's College, London; and to various missionary and other religious

societies where texts in Hausa will be accessible and useful to students. The usual copies have also been deposited in pursuance of the Copyright Acts. There remain three copies in hand which the Committee hope to distribute in a similar way shortly.

The Prehistoric Civilisation of the Western Mediterranean.—Report of the Committee, consisting of Professor W. RIDGEWAY (*Chairman*), Dr. T. ASHBY (*Secretary*), Dr. W. L. H. DUCKWORTH, Mr. D. G. HOGARTH, Sir A. J. EVANS, *and* Professor J. L. MYRES, *appointed to report on the present state of knowledge of the Prehistoric Civilisation of the Western Mediterranean with a view to future research. (Drawn up by the Secretary.)*

OUR knowledge on this subject has made considerable progress in recent years, though one of the main hypotheses—that of the advance of the so-called 'Mediterranean' race (to which several scholars attribute the megalithic civilisation of the end of the Neolithic and the dawn of the Bronze Age) from North Africa—has yet to be tested by further research in Tripolitania and Cyrenaica, which we may hope that Italian archæologists will shortly be able to undertake. In the meantime, the megalithic remains of Malta have been studied to some extent by the British School at Rome, though more work might be profitably undertaken there; a considerable number of dolmens are now known in Sardinia; and a new group of them has recently been found in the neighbourhood of Bari, in the south-east of Italy.

It would be important to study the intermediate links in the chain, which seems to connect the megalithic civilisation of the Western Mediterranean with that of our own islands: and the dolmens of Spain and Portugal might with some profit be further examined.

The Teaching of Anthropology.—Report of the Committee, consisting of Sir RICHARD TEMPLE (*Chairman*), Dr. A. C. HADDON (*Secretary*), Sir E. F. IM THURN, Mr. W. CROOKE, Dr. C. G. SELIGMANN, Professor G. ELLIOT SMITH, Dr. R. R. MARETT, Professor P. E. NEWBERRY, Dr. G. A. AUDEN, Professors T. H. BRYCE, P. THOMPSON, R. W. REID, H. J. FLEURE, *and* J. L. MYRES, *and* Sir B. C. A. WINDLE, *appointed to investigate the above subject.*

THE President of Section H, Sir Richard Temple, initiated a discussion at the Birmingham Meeting on the practical application of anthropological teaching in Universities. A report of this discussion was printed in *Man*, 1913, No. 102, giving the President's opening statement, extracts from letters from distinguished administrators and ethnologists, and an abstract of the speeches made by Sir Everard im

Thurn, Mr. W. Crooke, Lieut.-Colonel Gurdon, Dr. Haddon, Dr. *Marett, and Professor P. Thompson.*

A Committee was appointed by the British Association for the purpose of devising practical measures for the organisation of anthropological teaching at the Universities in the British Islands. With this committee was associated a committee appointed by the Council of the Royal Anthropological Institute. These committees met in joint session at the Institute, under the chairmanship of Sir Richard Temple, and passed the following resolutions: '(*a*) It is necessary to organise the systematic teaching of Anthropology to persons either about to proceed to, or actually working in, those parts of the British Empire which contain populations alien to the British people. (*b*) The organisation can best be dealt with by the collaboration of the Royal Anthropological Institute, the British Association, and the Universities, with the support and co-operation of the Government, the Foreign Office, the India Office, the Colonial Office, and the Civil Service Commissioners. (*c*) It would be well for the organisation to take the form of encouraging the existing Schools of Anthropology at the Universities and the formation of such schools where none exist. (*d*) As laboratories, a library, and a museum, readily available for teaching students, are indispensable adjuncts to each school, it is desirable to encourage their formation where they are not already in existence.'

By the courtesy of the Master and Wardens of the Worshipful Company of Drapers of the City of London, a conference to consider the findings and recommendations of the Joint Committee was held in the Hall of that Company on February 19, 1914. The President of the Conference was the Right Hon. the Earl of Selborne. A large number of representatives of various Home and Colonial Government Departments, Universities, Societies, as well as politicians, administrators, and others, were present or sent letters of regret at their inability to be present at the Conference, and expressing their sympathy with the purpose of the Conference. A full report of this Conference will be found in *Man*, 1914, No. 35.

In November 1913 Sir Richard Temple addressed the Indian Civil Service students at Exeter College, Oxford. In February 1914 he published a pamphlet entitled 'Anthropology a Practical Science,' which included his Birmingham Address (1913), an Address delivered in Cambridge in 1904, and extracts from that given at Oxford (1913). In March he addressed the American Luncheon Club, and also the Sphinx Club, both mercantile institutions, on Anthropology in its 'business' aspects. And he has engaged to do the same at the Merchants' Luncheon Club at Hull.

It has not yet been possible to place the findings of the Conference before the Prime Minister, whose time has been, and is still, taken up with urgent matters of State. An endeavour to secure an audience with the Prime Minister will be made when an opportune moment arrives.

The Ductless Glands.—Report of the Committee, consisting of Professor Sir EDWARD SCHÄFER (*Chairman*), Professor SWALE VINCENT (*Secretary*), Professor A. B. MACALLUM, Dr. L. E. SHORE, *and* Mrs. W. H. THOMPSON. (*Drawn up by the Secretary.*)

MR. A. T. CAMERON has continued his investigations on the presence and function of iodine in different tissues. Examination of the thyroids of the elasmobranchs *Scyllium canicula* and *Raia clavata* gave positive results, those for female *Scyllium* thyroids (1·16 per cent.) being higher than any previously reported.[1] Examination of the thyroids of the dog-fish *Acanthias vulgaris*, of the frog, of the alligator, and of the pigeon gave positive results, the variations found being traceable to variations in diet. Comparison of the iodine content of thyroid and parathyroid tissue in the dog gave such marked differences as to warrant the assumption that the parathyroid is not concerned with the production of iodine compounds, and, therefore, as far as these are concerned, that there is a differentiation of function between the two glands.[2]

A wider investigation has shown, in comparison with data previously published by others, that iodine is an almost invariable constituent of all organisms, plant and animal, the amount depending on the diet and medium of the organism. With higher development there is greater specificity of the tissue concerned in storing iodine, until in the vertebrates no tissue except thyroid contains appreciable quantities. Thymus especially has been examined in a large number of species, with negative results. All normal thyroids contain iodine, the amount varying with the diet, and between the limits 0·01 and 1·1 per cent. (dry tissue). Other observers have shown previously that sponges and corals (besides many algæ) contain quantities of iodine comparable with that in the thyroid. Three other types of tissue have been found in marine organisms which contain amounts of iodine over 0·1 per cent. (dry tissue) viz.: the horny tubes of Eunicid worms, the external cutaneous tissues of the 'foot' of the horse-clam, and the test of a tunicate. Further work will be carried out to determine the type of iodine compound in these tissues, with a view to throwing further light upon the type of iodine compound in the thyroid. The above results are in course of publication.

Mr. Cameron is also engaged in work on the effects of feeding iodine compounds (and thyroid) on the amount of iodine present in the thyroid gland, with a view to determine the rate of increase or diminution. These results are not yet ready for publication.

The Secretary has been engaged upon various problems connected with the ductless glands. The effects of varying conditions upon the histological structure of the thyroid and parathyroid have been investigated in a preliminary fashion, but the results are conflicting and difficult to interpret. The variations in structure in normal thyroids

[1] *Biochem. J.*, **7**, 466, 1913. [2] *J. Biol. Chem.*, **16**, 465, 1914.

are so great that the effects of feeding, drugs, &c., cannot be summarised in a definite manner.[3]

The pharmacodynamics of different extracts have also been studied. Among other facts to which attention will be called in subsequent publications it may be mentioned that large doses of adrenin by no means always interfere with the normal action of the vagus, that the rise of blood-pressure due to injection of adrenin is of a double nature, and that comparatively small doses of the last-mentioned drug frequently cause an unexpected fatal result in dogs.

The effects of adrenin and thyroid extracts upon the activity of the vagus have led to an inquiry as to the effect of hormones upon vaso-motor reflexes, and owing to the unsatisfactory accounts given in the majority of books as to the actual facts in connection with these reflexes, it has been necessary to extend the inquiry so as to include a consideration of the vaso-motor reflexes in general. So far, the only hormone which appears to give any interesting results is the extract of pituitary, the effect of injection of the extract being to change the nature of the reflex, so that in cases where, for example, stimulation of the central end of the sciatic produces a fall of blood-pressure, after injection of pituitary extract a similar stimulation produces a rise.

This work is nearly ready for publication.

The Committee desire to be reappointed with a grant of 40*l.*

Calorimetric Observations on Man.—Report of the Committee, consisting of Professor J. S. MACDONALD (*Chairman*), Dr. F. A. DUFFIELD (*Secretary*), *and* Dr. KEITH LUCAS, *appointed to make Calorimetric Observations on Man in Health and in Febrile Conditions.* (*Drawn up by the Secretary.*)

IN furnishing a report upon the calorimetric work undertaken during the past year, it is necessary to refer to a paper published by Professor Macdonald and printed in the 'Proceedings of the Royal Society,' B, vol. 87, 1913, and to a communication to the Physiological Society, May 1914. The commencement of the first paper, containing a description of the apparatus and of the method of procedure followed in these experiments, may be omitted here, since these have been included in previous reports of this Committee. The latter part, which is the collected and digested results of a very large number of experiments made upon a variety of individuals, forms a large part of this report.

The experiments all through have been carried out by Professor Macdonald with the apparatus and in the manner already described by himself in the earlier reports. The subject, shut up within the calorimeter, was made to perform a definite measured amount of mechanical work upon the cycle. The degree of work was varied in different experiments, and from the data of these heat-production

[3] See discussion, *Lancet*, 1914 (March and April), by Bell, McGarrison, Chalmers, Watson, and Vincent.

figures have been obtained which fall into four groups corresponding to the grades of mechanical work done. It has been found that these results may be expressed by a constant multiplied by a function of the subject's weight, which varies with the amount of mechanical work performed in the different groups, *i.e.* ·02, ·03, ·07 and ·09 h.-p.

$$\text{Group A—Heat-production} = K_a W^{4/3}$$
$$\text{,, B— ,,} = K_b W^{2/3}$$
$$\text{,, C— ,,} = K_c W^{1/3}$$
$$\text{,, D— ,,} = K_d$$

From these results it is evident that the weight becomes less and less of a handicap as the mechanical work increases. And, to carry this a stage further, the query arises as to the likelihood of the weight becoming a positive advantage at a still higher grade of mechanical work.

The communication to the Physiological Society contains a formula for one of the subjects cycling at a revolution rate varying from 40 to 98 revolutions per minute, and performing external work against a brake varying in different experiments from 0 to 73 calories per hour—

$$48V^{\frac{V}{251}} + \frac{56{\cdot}3}{W^{2/3}} \times \text{work in Kals. per hour} = \text{Kals. per hour.}$$

The first part of the formula represents the heat-production associated with the rate of movement 'V,' and is the same no matter what the value of the external work performed by the movement. The second is the 'coefficient of efficiency' multiplied by the external work done, and fully represents the heat-production associated with the performance of external work. It will be noticed that this coefficient of efficiency is represented as varying inversely with the two-thirds power of the subject's weight, and that the 'efficiency' which is its reciprocal therefore varies directly with this value. This has been found universally the case in the data from all the remaining subjects, and explains the fact that in the heavier work experiments the results become independent of the subject's weight, if consideration is paid to the other fact, also elicited from these data, that the heat-production associated with movements *per se* (irrespective of the mechanical work performed by them) varies, on the other hand, directly with the function of the weight. In fact the total energy transformation is the sum of the two factors, one due to the subject's movements *per se* varying directly, the other due to performance of mechanical work in the course of these movements varying inversely as the subject's weight; but in neither case in a simple linear fashion. The general formula given (Proc. Physio. Soc., March 1914), is

$$87WV^{\frac{VW^{\frac{1}{3}}}{1878}} + \frac{56.8}{W^{\frac{1}{3}}} \times \text{work.}$$

The first fraction is probably expressible in the following form—$KWV^{\frac{KV}{v}}$; where 'v' is the natural rate due to the 'pendular character' of the limb movements, and V is the particular rate imposed in each experiment.

Professor Macdonald also finds analogies between these results and those of walking experiments described by Douglas and Haldane in 'Phil. Trans.' B, ciii., p. 245. A full consideration of the matter will be found in a paper communicated, June 1914, to the 'Proc. Roy. Soc.' on the 'Mechanical Efficiency of Man.'

The section of the work dealing with the respiratory changes has also been continued during the past year. A number of experiments have been performed in which the respiratory interchange of a man, doing a measured amount of mechanical work upon a cycle in the calorimeter, has been investigated. The calorimeter is ventilated by means of a stream of air drawn through it at a uniform rate by a pump and measured by a meter placed on the distal side of the latter. All three are connected by tubing, through which the air flows, and the air as it leaves is sampled by suitable means every ten minutes. The samples thus obtained are examined by the gas-analysis apparatus devised by Dr. Haldane, and the carbon dioxide and oxygen percentage determined. The carbon dioxide figures, when plotted against the time on squared paper, take the form of a curve rising steadily to a horizontal asymptote.

In order to understand the figures thus obtained it was obviously necessary to inquire into the question of storage of gases within the calorimeter, and to do this a number of calibration experiments (17 in all) were made, in which a stream of carbon dioxide, measured by a gas-meter and generated by a modification of the apparatus described in a paper by Young and Caudwell ('Soc. Chem. Ind.,' March 1907), was passed into the calorimeter at a uniform rate, and the ten minutes' samples examined in the manner described in the experiments on the human subject. Attempts were then made to discover the relation which exists between the curve of the carbon dioxide in the leaving air and that of the carbon dioxide introduced from the generating apparatus; but so far the results appear so complicated that no definite relation has been arrived at. However, quite recently Mr. G. H. Livens, M.A., Lecturer on Mathematics to the University, has rendered most valuable assistance towards solving this problem. A fairly accurate empirical formula has been obtained from the actual readings, but it is not of such good agreement with the theoretical formula as is desired, and further experiments are being made to detect the cause of the discrepancy.

Owing to the appearance of a considerable error in the readings of the large meter used for measuring the volume of the air-flow through the calorimeter, it became necessary to replace it by a water-meter supplied by Messrs. Parkinson and Cowan, Ltd. Also, a large number of tests were made, both in the Physiological Laboratory and through the courtesy of the Sheffield Gas Company at their test-room, on the small meter which is used for measuring the volume of carbon dioxide introduced into the calorimeter in the calibration experiments mentioned above. I am now certain that the error in our estimation on these accounts is well under 2 per cent.

The Effect of Low Temperature on Cold-blooded Animals.—Report of the Committee, consisting of Professor SWALE VINCENT (*Chairman*) *and* Mr. A. T. CAMERON (*Secretary*). (*Drawn up by the Secretary.*)

MR. A. T. CAMERON has continued the experiments of Cameron and Brownlee on frogs communicated in the last report, and has arrived at the following conclusions:—

(1) The death-temperature of *R. pipiens* from cold is $-1{\cdot}25^\circ \pm 0{\cdot}15^\circ$ C.

(2) There is no climatic adaptation, nor any periodic adaptation due to hibernation, in *R. pipiens.*

(3) The cause of death is a specific temperature effect on the co-ordinating centres in the central nervous system. Those controlling lung-respiration may be specially concerned.

(4) Frogs surviving degrees of cold such as those occurring during a Manitoban winter do so below the surface, near the margin of springs, and are themselves never subject to temperatures below the freezing-point of water.

(5) There seems to be a slight variation in the death-temperature from cold, of different species of frogs, amounting to some tenths of a degree Centigrade.

(6) Frogs heated rapidly to normal room-temperature from a temperature just below the freezing-point of their body-fluids (and not itself capable of causing death) are thrown into a peculiar hypersensitive condition, in which cessation of lung-breathing takes place for long periods.

These results are deduced from experiments with *R. pipiens* from Manitoba, Minnesota, and Illinois, with *R. clamitans* from Minnesota, and with *R. sphenocephala* from C. Carolina. The experimental details will be published elsewhere. The Committee do not wish to be re-appointed.

Miners' Nystagmus.—Interim Report of the Committee, consisting of Professor J. H. MUIRHEAD (*Chairman*), Dr. T. G. MAITLAND (*Secretary*), Dr. J. JAMESON EVANS, *and* Dr. C. S. MYERS, *appointed to investigate the Physiological and Psychological Factors in the Production of Miners' Nystagmus.*

Factors concerned: (*a*) Internal; central and peripheral. (*b*) External.

Two features have long been admitted to be provoking agencies in the production of miners' nystagmus—an external factor, defective lighting, and an internal or peripheral factor, viz., muscular strain. The former, defective lighting, is found to be the more important, and our examination led us to conclude that where this factor is in greatest evidence there we find the greatest incidence of cases. Miners' nystagmus is a disease limited practically to coal-mining, and, further, it is associated with the use of lamps of small illuminating power, such as the Davy

or its modifications, so that it is rare, even in coal-mines, to find cases of nystagmus where more powerful illuminants such as candles and electric lamps are used. Moreover, the great absorption of light by the coal-surface diminishes the illuminating value of the lamp employed. This absence of reflections from walls, floor, and ceilings interferes with clear visualisation, since direct rays are never so satisfactory as diffuse rays. The other factor mentioned above—muscular strain, especially of the elevators of the eyeballs—is also taken into consideration, notwithstanding the difference of opinion on the importance of this. Snell has collected several cases of nystagmus which, as in the case of compositors, has followed strain in this way, and we have ourselves found that there is a larger number of cases of miners' nystagmus associated with 'holing' than in any other occupation underground—under conditions, therefore, which demand an awkward posture with straining of the head and eyes. Other sources of peripheral irritation are opacities of the media, errors of refraction, pigmentary and other ocular defects, which tend to produce or aggravate nystagmus by either modifying illumination or by causing muscular strain or by interfering with the direct rays on the fovea.

Taking all these factors, however, into consideration—factors which are generally acknowledged—the fact remains that, working under similar conditions of illumination and strain, a large percentage of miners do not develop nystagmus, and it is our object to find out what is the decisive factor. Admitting the external factors in those who develop nystagmus to be more or less constant, admitting the occasional possibility of peripheral factors such as those above mentioned, there remains some factor unaccounted for which explains the selection of certain miners for this trouble. At this stage of our inquiry, however, we investigated what seemed to us a neglected field—the relative sensibility of the retina in the foveal and in the perifoveal regions—and for this reason. The peculiar modifications which the dark-adapted eye undergoes might bring about a still further interference with the illumination by a reactive function on the part of the percipient.

A consideration of the conditions of work in the coal-mine suggested very strongly the importance of the possession by the miners of delicate vision sensibility. Before dark-adaptation could be fully developed the miner at his first entry into the pit would have to strain his vision under the most trying circumstances to avoid roof obstacles as he made his way to his work. Such a strain would display itself in the muscles chiefly involved, such as the elevators of the eyelids and of the eyes. It is interesting clinically to find the initial symptom complained of is a heaviness of the lids.

At work on the coal-face the miner with his eyes on the coal-surface would be subjected only to a few reflected rays from smooth facets of coal and some little diffused light from the coal-surface generally. Very dim light would bring out the latent differences in the visual sense, such as the differences of acuity between foveal and perifoveal vision. If the rays were too feeble to excite foveal sensation they might yet stimulate perifoveal sensation.

Our theory regarding this particular feature of the eye was that a

perifoveal sensation, in the absence of foveal sensation, or a perifoveal sensation of greater intensity than a foveal sensation, would excite a fixational or movement reflex. This would bring the exciting point in the marginal field on to the fovea, and would then either cease altogether to excite sensation or would be so diminished in intensity as to lay the eye open again to marginal stimulation. With a central stigma, a neurasthenic diathesis, there would be present all the material for the development of a habit spasm.

A large number of observations were made on students, assistants, and ourselves with a piece of apparatus described* in the appendix. This apparatus was arranged to present a spot of light the intensity of which was controllable. The open eye was directed on this spot while the room was in full daylight, and then the room was suddenly plunged into darkness. At the end of five seconds the subject was examined as to his ability with direct vision to perceive this faintly illuminated spot, its intensity rapidly altered until the subject was only just able to perceive it. The time for this, the minimum visibile, usually took about five seconds, and the degree of illumination was remarkably constant in all these cases, so much so that we were able to fix on this degree of light intensity as our zero. The direct vision was contrasted with indirect vision, the subject being directed to look slightly away from the spot of light, which at once appeared to become more vivid. The intensity was then diminished until here again the spot was only just discerned, and so we obtained a minimum vision visibile for indirect or perifoveal vision.

At intervals of two and a half minutes the minimum visibile was estimated for both fovea and perifovea, and we were able to represent in graphic form the increasing sensibility of the retina to faint illumination. In general the dark adaptability of fovea and perifovea increased rapidly up to the end of half an hour, less rapidly up to the end of two hours; arriving then at its maximum sensibility it remained stationary. The perifovea throughout this development of dark adaptation not only retained its primary advantage, but slightly increased that advantage up to the limit of change. In our experience in the coal-mines we never, however, felt that the maximum amount of sensibility was ever in demand, and while the light was indeed feeble enough to be excessively irritating to our unaccustomed eyes, yet nowhere did we find working conditions approaching our experimental conditions. Was the miner's eye differently equipped from our own, did it possess a greater adaptability through use and habit?

This led to an examination of the dark-adaptability of miners who had been afflicted with nystagmus, and here we found without exception a totally unexpected condition, yet one which now rendered plausible our fixational hypothesis. Instead of finding a greatly increased adaptability as a result of long use and cultivation of the eye in the dark, we found that in this respect it was greatly inferior to the 'normal' eye. In the first place the 'zero' was not perceived until after about five minutes of exposure to the dark, and then once perceived it remained without an appreciable development through the two hours' experiment. This peculiarity on the subjective side amounted to the same thing in

its effects as a modification of the external factors of the illumination, so that the differences observed in the normal eye, under the experimental condition described above, might in the case of the miner come into operation under the condition of his work owing to the altered sensational values following retinal insensitiveness. The fact is that the theory of 'fixational reflexes' might yet be true of the behaviour of the miner's eye in the coal-mine.

The conclusion of the research so far then seemed more and more to lay stress on the one well-recognised agency, that of illumination, and that insensitiveness of the retina really amounted to the same thing as an absolute decrease in the illuminant.

There remains for examination the actual excursion of the eye, and an examination into the nervous system of the afflicted miner.

Since this was written an examination of unaffected miners has been made, with the result that there is no appreciable difference between their dark-adaptability and what we describe as the normal.

The Apparatus for estimating the Minimum Light Sensibility in the Process of Dark-adaptation.

It consists of an oblong box, the front of which is pierced by a round hole with a diameter of 20 mm., which is covered by an opal disc. At the back of the box exactly facing this aperture is a sheet of white paper which reflects light thrown upon it on to the disc. At the side of the box is another aperture into which a tube nearly 2 m. long fits. This tube carries within it a small 2-volt lamp which can be moved quite freely from end to end. The light from this lamp is thrown on a mirror so placed that it reflects this light on to the sheet of paper, which then reflects it on to the disc. It was only in this way the light could be sufficiently diminished to obtain marginal stimuli.

After a number of experiments we arbitrarily decided upon our zero—that is, the light that could be only just perceived five seconds after the room was plunged in darkness. At intervals of two and a half minutes the subject was tested again, and the lamp was gradually moved away from the box until the subject failed to perceive the disc.

The Investigation of the Jurassic Flora of Yorkshire.—Report of the Committee, consisting of Professor A. C. SEWARD (*Chairman*), Mr. H. HAMSHAW THOMAS (*Secretary*), Mr. HAROLD WAGER, *and* Professor F. E. WEISS.

THIS year attention has been concentrated on the plant beds on and near Roseberry Topping, North East Yorkshire, more especially on the Thinnfeldia beds. A careful search was made for the reproductive structures of *Thinnfeldia*, and this was rewarded by the discovery of numerous associated seed-like bodies, whose structure has yet to be investigated, and which may, perhaps, prove to belong to this plant. A new example of a *Williamsoniella* flower-bud was found, which is of interest in greatly extending the range of this form. Some fruits and seeds, probably referable to the provisional genus *Caytonia*, were also discovered, though they were previously known only from Gristhorpe. One or two new forms were found, and many duplicates of the more interesting species were collected. It is not proposed to continue field-work and collecting in the future on the same scale as

during the past three years until the existing collections have been fully investigated.

The Committee does not seek re-appointment.

The Vegetation of Ditcham Park, Hampshire.—Interim Report of the Committee, consisting of Mr. A. G. TANSLEY (*Chairman*), Mr. R. S. ADAMSON (*Secretary*), Dr. C. E. MOSS, *and* Professor R. H. YAPP, *appointed for the Investigation thereof.*

SINCE the date of the last report a large number of experiments have been carried out with evaporimeters. Especially, a large series of simultaneous readings have been taken, covering a considerable period, from instruments placed in various positions in beech-woods, coppices, and in open grassland. Several of the results suggest further lines of experimentation and research, but a much larger number of readings must be obtained before any generalisation can be enunciated. The evaporimeter readings have been run concurrently with a series of readings of wet and dry bulb thermometers, and also of maximum and minimum thermometers which have been placed in association with the evaporimeters.

The work on soils has commenced, but so far has been mainly preliminary. Experiments have been made on soil temperatures, especially in relation to exposure, drainage, woodland canopy, &c.

The general preliminary mapping of the various associations composing the area has been completed, and an analysis of them has been made from the topographical and floristic standpoints as a basis for experimental work in the coming season. In this connection special attention has been paid to the successive changes occurring after coppicing till the re-forming of the full canopy, and also to the question of the recolonisation by trees of cleared areas and grasslands. Data have been collected which serve as a starting-point for a more detailed study.

The areas enclosed against rabbits, &c., have also been under observation, and the changes occurring have been examined and recorded.

The Committee asks to be reappointed, without a grant.

Experimental Studies in the Physiology of Heredity.—Report of Committee, consisting of Professor F. F. BLACKMAN (*Chairman*), Mr. R. P. GREGORY (*Secretary*), Professor W. BATESON, *and* Professor F. KEEBLE.

THE grant of 30*l*. has been expended in part payment of the cost of experiments conducted by Miss E. R. Saunders, Mr. R. P. Gregory, and Miss A. Gairdner. Miss Saunders' experiments with stocks have had for their main objects:—

(1) The investigation of the condition known as half-hoariness and

its relations to the glabrous and fully-hoary forms. A new half-hoary race, which has been obtained after some difficulty, has made it possible to design a complete series of experiments, which is now in progress.

(2) The further study of the gametic coupling already shown to exist between the factors for double-flowers and plastid-colour. This investigation promises to give results of great interest, but a further generation must be raised before a statement can be made.

(3) A result of some interest is the discovery that the double-flowered plants, at least in some strains, have a more rapid and vigorous growth than the singles. It is thus possible, by means of selection based on this difference, to obtain a far higher percentage of doubles in the flower-bed than would be expected from the normal output of doubles by a double-throwing single.

(4) A beginning has also been made with the work of obtaining a complete series of types of known factorial constitution, so that a supply of material may be available for testing the view which has been put forward as to the inter-relations between the factors determining hoariness and sap-colour.

Experiments with foxgloves have been designed for the investigation of a curious condition of partial hoariness, as well as for observations on the range of variability in the *heptandra* form.

Experiments by Mr. Gregory with *Primula sinensis* have been designed chiefly with a view to the investigation of the cytology and genetics of certain giant races, which have been shown to be in the tetraploid condition; that is to say, they have $4x$ (48) chromosomes in the somatic cells and $2x$ (24) chromosomes in the gametic cells, whereas in the diploid races the numbers are $2x$ (24) and x (12) respectively. These experiments have given results of very great interest, which may be briefly summarised by saying that the reduplication of the chromosomes has been found to be accompanied by a reduplication of the series of factors. An account of this work has been published in the 'Proc. Roy. Soc.,' B., Vol. 87, p. 484, 1914, and it is hoped that a further statement will be made at the meeting of the British Association in Australia. Further experiments with these tetraploid plants are designed especially to investigate the phenomena of coupling and repulsion between certain factors. These experiments promise to yield results of very great interest, both as regards the genetics of tetraploid plants and as regards cytological theory as to the possible relations between factors and chromosomes.

In the experiments with the ordinary diploid races, an interesting case has been discovered in which the coupling between the factors for magenta and green stigma is on the system 7 : 1; whereas in a very large number of other experiments the coupling (or repulsion) between these factors is of a very low order, apparently less than 3 : 1.

A paper is in the course of preparation, and will shortly be published in the 'Journal of Genetics,' on the inheritance of green, variegated, and yellow leaves in Primula. The variegated plants consist of a mosaic of two kinds of cells, respectively like those of the pure green and pure yellow-leaved plants. The characters of the chloroplasts, on which greenness and yellowness depend, have been found to

be inherited through the egg-cell only, the male gamete playing no part in determining the nature of the offspring in respect of these characters.

The experiments of Mr. R. P. Gregory and Miss Gairdner on the inheritance of variegation and other characters in *Tropæolum* have been continued. It is hoped that sufficient data will have been gained by the end of the present season to permit of the publication of an account of this work. Present results indicate that in *Tropæolum* variegation is inherited in the usual way from both the father and the mother, and is a Mendelian recessive character. Other characters in *Tropæolum* which are being studied are those of colour and habit (dwarf or trailing).

The experiments on the gynandrous variety of the Wallflower and its relation to the normal type are nearing completion, and it is hoped that an account of them will be published next year.

The Committee ask for reappointment with a grant of 45*l.* The expenses of these experiments involve an annual outlay of about 110*l.* to 120*l.* By far the largest item in this expenditure is the cost of labour, which has increased during the last few years with the general rise in wages which has taken place. Other important items are those of the rent of the garden and the cost of heating the *Primula* house. During the present year Miss Saunders and Mr. Gregory jointly receive a grant from the Royal Society of 60*l.* in aid of the cost of this work.

Breeding Experiments with Œnotheras.—Report of the Committee, consisting of Professor W. BATESON *(Chairman)*, Professor F. KEEBLE *(Secretary), and* Mr. R. P. GREGORY, *appointed to carry out the Experiments.*

THE Committee have received the following Report from Dr. R. R. Gates on the experiments which he has made:—

'The grant of 20*l.* made by the British Association for *Œnothera*-breeding has been applied to the expenses of these experiments during the last year. In the season of 1913 about 10,000 plants were grown, representing a great many races and hybrids of *Œnothera.* The plants were grown at Rothamsted on a two-acre plot set apart for the purpose. They developed very successfully, nearly every individual reaching maturity. The largest series of hybrids were the F_3 from *Œ. grandiflora*, *Œ. rubricalyx* and its reciprocal, and the F_2 of crosses between *Œ. grandiflora* and *Œ. Lamarckiana.* The F_3 generation of the former cross confirms and extends the results of the F_1 and F_2 generations already published in 'Zeitschr. f. Abst. u. Vererb.,' vol. xi. They show in particular that both blending and alternative inheritance of characters occur. Some of the plants, which have been examined cytologically in conjunction with Miss Nesta Thomas, further emphasise the fact that mutation and hybridisation in *Œnothera* are separate processes, both of which may go on together. Some of these results will be incorporated in a book now in preparation.'

The Renting of Cinchona Botanic Station in Jamaica.—Report of the Committee, consisting of Professor F. O. Bower (*Chairman*), Professor R. H. Yapp (*Secretary*), Professors R. Buller, F. W. Oliver, *and* F. E. Weiss.

The Committee has met twice. The negotiations with the Jamaican Government are progressing favourably, the Committee having been assisted by the advice of Sir David Prain. There is every prospect of the house and buildings being let to the Committee on an annual tenancy to commence from October 1, 1914, at a rent of 25*l*. There has, however, been considerable delay, partly owing to the long posts, partly to the progress of papers through official channels.

As no agreement has yet been signed the grant of 25*l*. has not been drawn. But in view of the prospect of negotiations being completed on the terms above stated, the Committee ask that they may be reappointed, and that the grant of 25*l*. be carried over to the ensuing year as an unexpended balance.

Mental and Physical Factors involved in Education.—Report of the Committee, consisting of Dr. C. S. Myers (*Chairman*), Professor J. A. Green (*Secretary*), Professor J. Adams, Dr. G. A. Auden, Sir Edward Brabrook, Dr. W. Brown, Professor E. P. Culverwell, Mr. G. F. Daniell, Miss B. Foxley, Professor R. A. Gregory, Dr. C. W. Kimmins, Professor McDougall, Drs. T. P. Nunn, W. H. R. Rivers, *and* F. C. Shrubsall, Mr. H. Bompas Smith, Professor C. Spearman, Mr. A. E. Twentyman, *and* Dr. F. Warner, *appointed to inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.*

The Committee has to report the retirement of its Chairman, Professor J. J. Findlay, and the election of Dr. C. S. Myers in his place.

They have been engaged in collating the data which was provisionally reported upon at Birmingham, and hope to present the results in a definite form for the Manchester Meeting in 1915. The Committee asks to be reappointed, and applies for a grant of 30*l*., to include the unexpended balance from this year's grant.

Influence of School-books upon Eyesight.—Interim Report of the Committee, consisting of Dr. G. A. Auden (*Chairman*), Mr. G. F. Daniell (*Secretary*), Mr. C. H. Bothamley, Mr. W. D. Eggar, Professor R. A. Gregory, Mr. N. Bishop Harman, Mr. J. L. Holland, *and* Mr. W. T. H. Walsh.

In previous reports (1912 and 1913) reference was made to the injurious effect of shiny paper, in particular to the interference with binocular

vision which may result from excess of specular reflection. The Committee is investigating the proportion of specular to diffusive reflection in the case of books and writing-papers used in schools, and has received valuable assistance from Mr. A. P. Trotter, who has devised a gloss-tester. The Committee desires to continue this investigation in the hope of arriving at an objective standard the adoption of which would prevent injury to eyesight through the use of glossy paper, and therefore asks to be reappointed with a grant of *5l.* in addition to the unexpended balance of last year's grant.

Museums.—Report of the Committee, consisting of Professor J. A. Green *(Chairman)*, Mr. H. Bolton *and* Dr. J. A. Clubb *(Secretaries)*, Dr. Bather, Mr. E. Gray, Mr. M. D. Hill, Dr. W. E. Hoyle, Professors E. J. Garwood *and* P. Newberry, Sir Richard Temple, Mr. H. H. Thomas, Professor F. E. Weiss, *and* Mrs. J. White, *appointed to examine the Character, Work, and Maintenance of Museums.*

The Committee report that a detailed schedule of inquiry upon Museums has been drawn up and presented to the House of Lords by Lord Sudeley. It is hoped that the schedule will be issued by the Board of Education, and that the information obtained will be available for the purposes of the Committee. Opinions and reports have been obtained upon various sections of museum work and their relation to various divisions of Education. Other inquiries of a similar nature are also being made. Offers of assistance have been received from the American Association of Museums. Two members of the Committee will examine overseas museums during their journey to and from Australia and report.

A deputation will report upon the educational work of Museums in France.

The following questions are receiving special consideration:—

The requirements of (1) students; (2) school children; (3) general visitors to museums.

The Committee ask to be reappointed with a grant of *30l.*, including the balance, *7l.* *9s.* *2d.*, of last year's grant, now in hand.

On Salts Coloured by Cathode Rays.

By Professor E. GOLDSTEIN.

[Ordered, on behalf of the General Committee, to be printed *in extenso.*]

PERHAPS a part of the phenomena which I am about to discuss is already familiar to you all. I shall not bring forward many hypotheses. So you will perhaps ask why I should speak at all. And, in fact, apart from reference to certain facts not published hitherto, my intention is mainly to invite the interest of men younger and abler than myself in a class of phenomena which seem to constitute a new condition of matter, but on which very few have yet worked.

If cathode rays fall on certain salts—for example, common salt, or chloride of potassium, or potassium bromide—vivid colours are produced immediately on these salts.[1] Thus common salt becomes yellow-brown (like amber), potassium chloride turns into a beautiful violet, potassium bromide becomes a deep blue colour quite like copper sulphate. Here you see a specimen of common salt transformed in this way on the surface of the single crystals into a yellow-brown substance. I show also sodium fluoride, which takes a fine rosy colour.

The colours so acquired in a very small fraction of a second may be preserved for a long time, even for many years, if the coloured substances are kept in the dark and at low temperatures. But in the daylight, and also under heat, the colours will gradually disappear till the original white condition is reached again.

The colours of different salts are sensitive to heating in a very different degree. I could show you the yellow sodium chloride, prepared some months ago in Europe, but I cannot show you here the violet KCl and the blue KBr, because these colours, even in the dark, do not stand the heat of the Equator. The same salt, if dissolved, may keep very different colours, according to the medium in which it has been dissolved, even when the pure medium itself cannot be coloured at all by cathode rays. I am speaking of *solid solutions*, produced by fusing a small quantity—for instance, of common salt or of certain other alkali salts—together with a great mass of a salt which remains itself colourless in the cathode rays, as, for example, the pure potassium sulphate. Lithium chloride acquires a bright yellow colour in the cathode rays; but if dissolved in potassium sulphate a lilac hue is produced, as you may see in this specimen. Likewise the pure carbonate of potassium acquires a reddish tint, but after dissolving it in the potassium sulphate it becomes a vivid *green* in the cathode rays, as you see here.

Very small admixtures are sufficient to produce intense colours. So $\frac{1}{25000}$ of carbonate will produce the green colour in the potassium

[1] E. Goldstein, *Wiedem. Ann.* 54, 371; 60, 491; *Phys. Zeitschr.* 3, 149; *Sitzungsber. Berl. Akad. Wiss.* 1901, 222.

sulphate; even $\frac{1}{1000000}$ gives a marked colour, and an amount of certain admixtures, which I estimated as $\frac{1}{1000000}$ only, may produce a slight but quite perceptible colouration in some salts. So if you work with potassium sulphate which you obtain from chemical factories guaranteed as chemically pure, you may observe a set of different colours in these preparations under the cathode rays, by which you will detect the nature of the different small admixtures which adhere to the pretended pure preparations of the different factories. In this way a new analytical proof, much more sensitive than the ordinary chemical methods, is obtained, and impurities may be detected even when a certain specimen of salt contains more than a single impurity, because the colours produced by different admixtures generally disappear with different speed in the daylight or under rise of temperature. For instance, the ordinary potassium sulphate turns to a dark gray with a slight greenish tint at first. After a short while the very sensitive gray will disappear, simply under the ordinary temperature of the laboratory room, and a vivid green comes out. The gray hue indicates a very small amount of sodium chloride, $\frac{1}{1000000}$ or so, and the remaining green indicates the admixture of a carbonate. Here are some preparations of potassium sulphate each containing a single small admixture (K_2CO_3, Li_2CO_3, LiCl, KCl, KBr). You will notice how different are the colours of the originally white substance, varying from green to bluish gray, ash-gray, grayish blue, and violet.

By fractional crystallisation one may finally get a really pure preparation of potassium sulphate, which is no longer coloured by cathode rays (or only in a very slight degree, indicating minimal traces of sodium chloride). But there are other preparations which, so far as I know, cannot be acquired in pure condition by any means, not even by fractional crystallisation. I never came across a pure sodium sulphate—the purity exists only on the manufacturers' labels. Even the best preparations of this salt contain an amount of sodium carbonate which up to the present cannot be separated from it, not even by frequent fractional crystallisation. The colour produced by the small admixture, which always remains, is a very marked ash-gray. By an intentional further addition of sodium carbonate the colour becomes nearly black.

The question arises: What may be the cause of these colourations in pure salts and also in solid solutions of them? Shortly after the colours of the alkali salts had been discovered, an explanation was given[2], according to which the phenomenon mainly consists in a chemical reduction. For instance, in the case of potassium chloride the chlorine would be set free, while the remaining potassium is dissolved in the unaltered main quantity of the salt, colouring it at the same time. And it seemed a convincing proof for this theory when Giesel[3] and also Kreutz, simply by heating rock salt in the vapours of sodium or of potassium, produced colours in this rock salt quite similar to those produced by cathode rays. It seemed that

[2] E. Wiedemann and G. C. Schmidt, *Wied. Ann.* **54**, 618.
[3] F. Giesel, *Ber. D. Chem. Ges.* **30**, 156.

the problem was settled finally. However, it was soon discovered that the coloured Giesel salts, although they look to the eye quite like the cathode-ray salts, in all other respects behave quite differently. For instance:—

(1) The cathode-ray salts, as I mentioned before, are very sensitive to daylight: after an exposure to diffuse daylight of a few minutes—or in some salts even of several seconds only—the colouration diminishes, whilst the Giesel salts remain unaltered even when they are kept in full sunshine for days or even weeks.

(2) The cathode-ray salts, if dissolved in distilled water, show absolute neutral reaction; the Giesel salts are strongly alkaline.

(3) The cathode-ray salts give very marked photoelectric effects (as Elster and Geitel[1] observed); the Giesel salts are quite ineffective.

(4) Under certain circumstances, which will be mentioned further on, the cathode-ray salts may emit a phosphorescent light, the Giesel salts none at all. Therefore the question arose again, whether there is not a marked internal difference between the cathode-ray salts and the Giesel salts, and what is the nature of the latter?

I have succeeded in settling this question, having produced salts *by cathode rays*, the behaviour of which is in every respect *absolutely identical with the Giesel salts*. You may produce such substances if you allow the cathode rays to fall on the original salts not for a short moment only, but for a somewhat prolonged time, *until the salts are strongly heated*. Produced in this way the salts will keep colours; but the substances coloured in this way are *not* sensitive to light; they show no photoelectric effect; they give *strong alkaline* reaction, and they are not suited for phosphorescence—all like the Giesel salts. It is quite sure, and you may test it also directly by spectroscopic proof, that in this case, if for instance you have worked on sodium chloride, *the chlorine is set free*. Then of course an amount of free sodium is left, which dissolves itself in a deeper layer of unaltered sodium chloride, to which the cathode rays could not penetrate. I call these non-sensitive colours *the after-colours of the second* class, while the ordinary sensitive after-colours, produced in a short time on cool salts, are called after-colours of the first class.

Now, if the after-colours of the second class are identical with the Giesel salts, then, of course, the very different substances of the first class cannot be also identical with the Giesel salts. Therefore the question arises anew what is the nature of the first-class after-colours?

One observes with regard to solid solutions that the first-class colours depend not only upon the *metal* contained in the small admixture, but they vary greatly, for instance, in the case of the admixture consisting of potassium chloride or bromide or iodide. This indicates that the metals alone do not cause the after-colours. It becomes much more clear when we expose some ammonium salts to the cathode rays. (The ammonium salts are cooled by liquid air in the discharge-tube to prevent their evaporation.) Then you get strongly marked after-colours likewise; for instance, ammonium chloride becomes yellow-greenish, the bromide becomes yellow-brown, the iodide becomes brown, and the

[1] J. Elster and H. Geitel, *Wied. Ann.* **59**, 487.

fluoride a deep blue. In the daylight these colours are gradually destroyed, quite like other after-colours of the first class. The colours themselves—yellow-greenish for the chloride, yellow-brown for the bromide, and so on—induce us to presume that the after-colours in this case are produced by the haloids, and not by the hypothetical ammonium radical. This presumption becomes a strong conviction when we observe that also a great number of organic preparations which contain no metal at all (and not any metal-like radical) acquire marked after-colours of the first class in the cathode rays also. (The part of the discharge-tube which contains the organic substances is cooled by liquid air.)

Then you may observe that solid acetic acid ($C_2H_4O_2$) remains quite colourless in the cathode rays; but if you substitute a hydrogen atom by chlorine, the substance thus produced (the monochloro-acetic acid) acquires a marked yellow-green after-colour. If you introduce an atom of bromine instead of chlorine, you get $C_2H_3BrO_2$ and the after-colour is of a marked yellow. Bromoform ($CHBr_3$) turns into the colour of loam, and chloral (C_2HCl_3O) becomes a deep yellow. In this way we see that not only salts, but likewise substituted acids, substituted hydrocarbons, and substituted aldehydes acquire after-colours if they contain any haloid.

Now, it seems highly improbable that in the case of alkali salts the electro-positive component is absorbed only (producing the after-colour), and that, on the other hand, in the ammonium salts and in the organic substances the electro-negative component is efficient only. The most probable inference is that in each case *both* components remain and that both are efficient, but that under the same conditions the haloids produce a slighter colour than the metals, so that in the case of the salts the haloid colour is overwhelmed by the metal colour.

Therefore we are compelled to suppose that we have not to deal with a decomposition in the ordinary form, by which the different components are finally separated from each other and at least one of them is set entirely free, but that the components detained by absorption remain at a quite short distance from each other, so that they may easily meet again. I realise that—for instance, in the case of sodium chloride—at every point of the coloured layer there is an atom (or perhaps a molecule) of chlorine and an atom (or a molecule) of sodium; but they cannot combine, because they are fixed by absorption and distended from each other by the absorptive power, which in this case surpasses the chemical affinity. But the absorptive power may be weakened by heating and the chemical affinity or the amplitude of the molecular vibrations may be strengthened by the energy of daylight.

If we grant these assumptions, it is immediately evident why the reaction of all dissolved colour substances of the first class is a neutral one, for the two components may combine again and re-establish the original substance. The other special qualities of the first-class colours, and especially their differences from the Giesel salts, which contain the electropositive component only, may be deduced likewise from this retention of both components and their opportunity of meeting each other again when the absorptive power is

weakened or the chemical affinity is strengthened. Now, the two components in the coloured substances being distended in some degree, I propose for this special condition of matter the name of *distension*. If we accept this, have we created a new name only, or does matter in this condition really show new qualities? It seems to me that we have to deal with a peculiar condition of matter, which deserves a more elaborate study than it has met till now. I will not enter again into some special qualities, which have already been mentioned—the photoelectric effect and so on—but I should like to point out that matter in the distension state shows a strongly strengthened absorption of light.

We noticed with regard to ammonium chloride the yellow-greenish after-colour of the chlorine. Now, cathode rays, as used in these experiments, will not penetrate any deeper than one-hundredth of a millimetre into the salt. In such a thin layer even pure liquefied chlorine would not show any perceptible colour. But besides this it must be noticed that we observe this after-colour at the temperature of liquid air, and that chlorine at this temperature, as Dewar and Moissan observed, is snow-white, even in thick layers. In a similar degree the brown colour of bromine is weakened at low temperatures. Now, if nevertheless we observe at this very low temperature the marked characteristic colours of chlorine and bromine, we must conclude that the absorptive power of these substances has become a multiple of its ordinary value. One may observe this strengthening of the absorptive power directly in the pure sulphur. Sulphur likewise turns into a snow-white substance if cooled by liquid air. But when the cathode rays fall on the white sulphur it takes immediately a yellow-reddish colour. It is a real after-colour, because at constant low temperature the colour is destroyed by daylight.

Now, since the strengthening of light-absorption occurs in this elementary substance, it becomes evident that the cause cannot be any chemical process, but only a physical allotropy. The special character of this allotropy (which may be connected with an absorption of electrons) will not be entered on in a discussion here. Probably we have to deal with a polymerisation, so that, for instance, the yellow-reddish sulphur would be analogous to polymerised oxygen—to ozone.

I have mentioned already that the first-class after-colours are gradually destroyed by incident daylight. A peculiar phenomenon is connected with this destruction of colour. I found that after the daylight had fallen on the coloured substances, even for the shortest time, most of them showed a marked phosphorescence of long duration. I have observed this phosphorescence even in substances which had been coloured twelve years ago and had been kept in the dark since that time. The diffused dim light of a gloomy November day, when falling through a window on the coloured substance for one or two seconds only, is sufficient for the production of this phosphorescence in a marked degree. If you allow the daylight to fall several times on the same spot, then the colour is weakened at this spot, and we come to the presumption that the loss of colouration is generally

attended by the emission of phosphorescent light. This is in accordance with the experience of Wiedemann and Schmidt that if the destruction of the colour is produced by heating, likewise a phosphorescent light is produced, which in this case is strong but of a short duration, corresponding to the quick destruction of the after-colours by strong heating.

If the salts, after having been coloured in the condition of a fine powder and then having been put between two glass plates (in order to obtain a plane surface), are placed in a photographic camera instead of the photographic plate, you may get a fine phosphorescent picture of a landscape or of architecture after a very short exposure.

Time does not allow me to mention in detail several other peculiarities which are shown by matter in the distension state. In one direction only I may be allowed to make some remarks.

The first-class after-colours may be produced not only by cathode rays but also by the β rays of radioactive substances, as you probably know. But they may also be produced by *ultra-violet light*, for instance, by ultra-violet spark light, even when a quartz plate is interposed between the spark and the salt. More than thirty years ago I brought forward a hypothesis, according to which in every point where cathode rays strike a solid body a thin layer of ultra-violet light-radiating molecules is produced in the gas, to which ultra-violet light of very short wave-lengths, for instance, the phosphorescence of the glass walls in the cathode rays, is due. But I came further to the assumption that nearly all effects which are commonly ascribed to special qualities of the cathode rays, and likewise of β rays and x rays, are mere effects of the ultra-violet light which is produced by the stopping of these rays. I have been guided by this assumption during many years, and have very often been aided by it in foreseeing new phenomena. For instance, in this way I was induced to expect that the after-colours would be produced not only by cathode rays but also by the ordinary ultra-violet light; further I could guess that also the x rays would produce after-colours (which in this case have been observed by Holzknecht), and in recent times I could foresee that solid aromatic substances (the benzene derivatives) in the ultra-violet light must change their spectra of ordinary phosphorescence, composed of broad bands, and turn to peculiar spectra composed of narrow stripes, the wave-lengths of which are characteristic of the single aromatic substances.[5] So I believe also that the after-colours are produced not directly by the cathode rays or by β rays, but by the aforesaid ultra-violet light which is connected with the stopping of the other rays.

In this way the after-colours enter at once into a great class of phenomena known as *reversible effects of light*. You know that certain effects of the visible spectral rays are destroyed by rays of longer wave-lengths, by the infra-red rays. And the analogy to this phenomenon is in my opinion the destruction of the after-colours: they are produced by the ultra-violet light of the stopped cathode rays and are annihilated by the longer visible wave-lengths of daylight. In this way you may likewise understand, for instance, that the coloured

[5] E. Goldstein, *Verhandl. d. D. Physik. Ges.* **12**.

spots, produced by x rays on the luminescent screens after long *exposure, may be destroyed* again by exposure of the screens to daylight. You may also explain the peculiar medical observation that therapeutic radium effects in parts of the human body not covered, specially in the face, are often not of long duration—for the face is exposed to the counteracting visible rays of daylight.

We notice here a connection of our subject with a department of great practical importance. For all therapeutic effects of x rays, radium rays, and mesothorium rays would, according to this view, be effects only of ultra-violet light produced by the stopping of these rays in the human body, and the special character of the radium- and mesothorium- and x-ray treatment would consist mainly in the carriage into the interior of the body, by the rays, of the ultra-violet light, which is not confined to the surface of the body, but is produced at every place where any of the entering rays are stopped. You may notice further that this view of the medical ray-effects presents a heuristic method for the treatment itself, which up to the present followed quite fortuitous and merely empirical paths. For it may be hoped that treatment by radioactive substances will be useful in every disease in which ultra-violet light has been proved to be efficient in some degree; you will avoid such treatment in the well-known cases in which light of short wave-lengths is noxious, and you may be justified in substituting an ultra-violet light treatment where radium or mesothorium is not obtainable. At the same time it becomes evident why the treatment of certain diseases by the β rays has effects very similar to those produced by *fulguration*—that is, by the light of very strong sparks: the efficient agent is in both cases the ultra-violet light.

But it cannot be a physicist's task to enter too far in medical questions: it was only my intention to show how interesting are some of the problems which are connected with the salts coloured by cathode rays.

The Problem of the Visual Requirements of the Sailor and the Railway Employee. By JAMES W. BARRETT, *C.M.G., M.D., M.S., F.R.C.S.Eng.*

[Ordered, on behalf of the General Committee, to be printed *in extenso.*]

THE discussions which have taken place on this subject are apparently interminable. They have for the most part resolved themselves into discussions amongst oculists and communications made by deputation or otherwise to the Board of Trade presenting their point of view.

The Board of Trade, whilst it has collected a certain amount of valuable information, has not materially modified its methods, and apparently does not propose to do so. As its authority weighs heavily in the Dominions, which are as a rule not consulted by it before it takes action, various anomalies make their appearance. I venture therefore to bring before this meeting of the Physiological Section of the British Association a summary of the present position.

Until recently the standard adopted by the Board of Trade was normal colour vision as tested by coloured wools and a form vision equal to 6/12 partly with both eyes open. In other words, the theoretical objective was normal colour vision, and form vision of such a standard that one eye might be totally blind and the other possess somewhat less than half vision. The Board, however, appointed an expert committee in 1910, which took evidence and made a number of recommendations. This committee sat for two years, and in its report recommended that the form vision required should be 6/6 in one eye and 6/12 in the other, and that colour vision should be tested by wools and by coloured lanterns. It did not, however, definitely recommend that the eyes of those who enter dangerous services should be subjected to a complete ophthalmological examination when the boy first goes to sea. Apparently such changes would have required fresh legislation.

Since this report, however, the Board of Trade has again altered its requirements, and now requires the candidate to read 6/9 partly and 6/6 partly with both eyes open, which means, simply, that the old standard has been reverted to as regards form vision, except that the minimum has been raised from 6/12 partly to 6/9 partly. During the course of its long inquiry the expert committee apparently did not consult those in the Dominions who were dealing with the matter, with the exception of the examination of two witnesses, nor did they apparently seek to make any careful reference to the various accidents which have taken place by sea and land and can be attributed to defective vision.

Clause 13 of the Report of the Departmental Committee on Sight Tests states:—'Sir Walter Howell informed us that the Board of Trade were not aware of any casualty which could be traced to defective vision. He explained that the Board could raise any question they pleased on an official inquiry into a marine casualty; that the smallest question as to the colour vision of any officer concerned would be probed to the bottom; that if there were any question of confusion the men concerned would be re-tested; but that such a question had not been raised in a single instance. We have examined a large number of the Reports of Board of Trade inquiries, and the result of our examinations has confirmed the view that no official evidence exists of casualties due to this cause. We have examined eight master mariners of long experience, none of whom knew of any case in which a casualty had arisen from defective vision.'

Clause 14.—'At our request the Liverpool Steamship Owners' Association ascertained that, of its members, the owners of 857 steam vessels, of the aggregate tonnage of 3,776,695 tons, knew of no instances in which mistakes due to defective form or colour vision had been made in the reading of lights at sea, and of no instance of difficulty of reading signals; while the owners of 59 steam vessels of 192,494 tons knew of some few instances in which a man's sight had been or had been alleged to have been defective, but of no casualty resulting therefrom.'

Clause 15.—'The Secretary of the Joint Arbitration Committee at Grimsby, which investigates the circumstances of a large number of collisions every year, has never known of a collision caused through

the mistaking of the colour of a light. The Manager of the Hull Steam Trawlers' Mutual Insurance and Protection Co., Ltd., who in 12 years has had to deal with an average of 100 collisions a year, knows of only four cases in which any question of defective vision has arisen. Two of these cases were in elderly men, and in the other two the witness considered the danger was caused by excessive smoking.'

Clause 17.—' The Board of Trade casualty returns, which include collisions to foreign ships on or near the coast of the United Kingdom and of British Possessions, show no case in which a sea casualty has been attributed to the defective vision either of an officer or a look-out man; but they show that since the adoption of the 1894 sight tests there have been reported on the average each year 100 collisions attributed to bad look-out and 429 strandings attributed to causes connected with navigation and seamanship. The strandings resulting from bad look-out are not shown separately. From these returns it is not possible to arrive at any reliable estimate of the total number that might have been occasioned by the defective vision of the officer in charge or of the man on the look-out. Further, the returns, as they do not distinguish the vessels commanded by officers who have passed the 1894 sight test, afford only a general basis of determining how far the existing system has been successful in eliminating dangerously defective men; but they do show that amongst the vessels registered in the United Kingdom the total number of collisions attributable to bad look-out and of strandings attributable to all causes relating to navigation and seamanship is less than 500 a year. The Board of Trade has no record of the actual number of voyages made by British vessels, but on a rough estimate that number cannot be less than 300,000 a year.'

Clause 18.—' There appears to be no evidence showing conclusively that defective vision has caused any appreciable number of accidents at sea, *although we do not think* that it necessarily follows from this that the present method, even where it has been employed, has been successful in excluding all dangerous persons from the Mercantile Marine, or that no accidents have been caused in this way, since it has not been the practice, in conducting inquiries into the causes of casualties, to test the vision of persons implicated. We think it regrettable that effect has not been given to the recommendation as to the testing of witnesses contained in the report of the committee of the Royal Society in 1894, and we desire to repeat that recommendation—that in case of judicial inquiries as to collisions or accidents witnesses giving evidence as to the nature or position of coloured signals and lights should be themselves tested for colour and form vision.'

Sir Norman Hill, who signed the Minority Report, states that ' in the absence of all evidence of any single casualty resulting from defective form vision I am opposed to the retention of the new standard under which 10 per cent. of the candidates who have for many years proved their competency would have been excluded from the service.' Mr. Nettleship, however, one of the members, since the publication of the Report, made a collection of the cases in which disaster at sea or land seemed to be actually or potentially due to these causes, and was in communication with the writer in regard to the details of a number

of other cases at the time of his death. In that work Mr. Nettleship makes the following pertinent observation (p. 3):—'For reasons such as the above, defects in sight are regarded by those who have to inquire into accidents as of such little importance that in the official investigations the question of defects of sight in the men who are on look-out or corresponding duty is scarcely ever raised. Naturally, therefore, no accidents are discovered to have had visual defects for their cause. Continuing to reason in a circle, the conclusion is that defects of sight do not cause accidents! It would be ludicrous if the matter were not so grave that though precautions of greater or less efficacy are taken to exclude men with conspicuous defects of sight from entering the sea or railroad services because such defects are admittedly dangerous, yet, when the accident happens, no trouble is taken to find out whether the man responsible for it has efficient sight or not. Every possible cause for the casualty is sought out, but the possibility that his vision either was defective when he entered the service or has become so since is never even considered.'

Yet in spite of the foregoing the fact remains that Dr. Orr and I reported in the *Lancet*, October 29, 1904, the account of the wreck of the *Australia* and the previous grounding of the *Indraghiri* by a pilot whose form vision was very defective. In spite of this Report, the statements of Sir Walter Howell and Sir Norman Hill appear in the Expert Committee's Report. I propose now to refer to the methods adopted in the Victorian Railways, the Victorian Pilot Service, and the Union S.S. Co. of New Zealand. The history of vision-testing in the Victorian Railways is too lengthy for detailed reference. The number of candidates who have to be dealt with is very large, and the Department has adopted a rough-and-ready plan with which I am not in complete sympathy, but which undoubtedly eliminates the majority of the defective cases. Colour vision is tested by the lantern and form vision by Snellin's types. For those entering the service the vision required is 6/6 in each eye and 6/6 in both together. The pupil is then dilated with homatropine and the vision is again tested. It must now not be less than 6/12 in each eye or 6/12 in both together. Once the applicants are admitted to the service they are re-tested without the use of homatropine, and must possess 6/12 vision in each eye and 6/9 in both together.

I propose now to indicate the steps that have been taken by the Marine Board of Victoria to provide for the thorough examination of the vision of pilots who enter their service, and for their re-examination since the disaster of 1904. I also quote Clauses 100, 102, 104 and 105 of the regulations which provide for the contingencies to which Mr. Nettleship referred.

Victorian Pilot Regulations.

Pilots must be examined prior to admission to the service, and their vision must be as follows:—

1. Vision to be 6/6 in each eye without glasses.
2. The total error of refraction not to exceed ·1 d. and of this

astigmatism not to exceed ·5 d. This estimate to be made by retinoscopy with the eye under the influence of a mydriatic.

3. The pupillary reflex to be normal, the fundus to be free from disease, visual fields normal, and balance of colour muscles to be normal. Candidate to possess binocular vision.

4. Colour vision to be normal as tested by coloured wools and coloured discs.

If persons possessing these qualifications are admitted, on re-examination the standard required is:—

1. The same as in the case of an applicant for a licence, except that after admission into the service deterioration of vision will be allowed, *provided* that the vision is not less than 6/9 fully and 6/6 partly in each eye.

2. There must be no evidence of any morbid or other condition in either eye which would render it probable that the vision would deteriorate before the next periodical examination.

Clause 100 provides that 'every pilot until he arrives at the full age of sixty years, whether licensed before or after the coming into force of these regulations, shall at intervals of not more than twelve calendar months, and in the case of a pilot who under the regulations does not necessarily retire at the age of sixty years, after he attains that age, at intervals of not more than six calendar months, have his eyes examined and vision tested, and pass as satisfying the prescribed standard by an expert oculist to be approved by the Marine Board.'

Clause 102 provides:—'If, on the occasion of any examination or testing of a pilot or of his eyesight or vision (whether biennial, sixth monthly, or casual) any physical, mental, or visual defect is discovered which in the opinion of the medical examiner or expert oculist, as the case may be, does not immediately, but may within a variable time, render the pilot unfit for service, such pilot shall submit himself for re-examination within such lesser intervals than those hereinbefore prescribed as the examiner or oculist, as the case may be, may certify to be necessary, any longer interval hereinbefore limited to the contrary notwithstanding.'

Clause 104 provides:—'In the event of any casualty or accident occurring to or in connexion with any vessel or incidental to the navigation thereof, which in the opinion of the Marine Board may be due to or of which in its opinion one of the contributing causes may have been some defect in health or vision of the pilot in charge, such pilot shall if required by the Board forthwith submit himself and be examined by a medical practitioner or expert oculist to be nominated by the Board, or by both, as the Board may direct, and until such practitioner or oculist or both, as the case may be, shall certify that such pilot is fit physically and mentally or visually, and such certificate be lodged with the Secretary to the Board, such pilot shall not follow his calling.'

Clause 105:—'If any pilot be absent from duty on account of illness, and such absence shall extend beyond twenty-eight days, or in case of illness of any duration, if the Marine Board think it advisable, or when from any other cause any pilot has been absent from duty and

such absence shall have extended for six calendar months or upwards, such pilot shall not return to duty unless and until, as regards his condition physical and mental, a medical practitioner and, as regards his vision and eyesight, an expert oculist, to be in both cases nominated by the Marine Board, have respectively certified to the Board that such pilot is in a fit condition physically, mentally, and visually to perform his duties as a pilot.'

The annual examination of the pilots has probably averted disaster, as one pilot was retired with high blood-pressure and retinal hemorrhages detected in the course of periodical examination.

The Union Steamship Company of New Zealand adopts a like standard for those who enter its service, and provides for periodical testing of form vision.

What standard of form and colour vision is necessary for safe navigation or railway service?

So far as colour vision is concerned the results of the ordinary tests with wools and lanterns seem to coincide with the quantitative measurements made by Sir William Abney, and I have never seen any practical difficulty in detecting a dangerous degree of colour defect by the combination of these means.

With regard to form vision, however, the matter is not nearly so simple. Two questions arise: What standard of form vision shall be required? and, Are two eyes necessary? Some time ago, in the *Ophthalmic Review*, Mr. Fergus gave an account of his own experience in motor navigation with defective vision. Apart from theoretical disquisition which I was unable to follow, he stated correctly enough that lowered form vision means for the most part a loss of detail. A house is still seen as a house at a distance when the form vision is lowered, and a ship is still seen as a ship in like circumstances. I, however, set to work to make myself artificially myopic with bi-convex glasses, and to reduce my form vision to different degrees in order to repeat his experience. In passing, however, it should never be forgotten that the standards given by Snellin's types are at best approximate. They depend on the illumination of the types, on the contrast between the letters and the background, on the illumination of the room, and the size of the pupil. They nearly always give better results in daylight than by artificial illumination. At best they have approximate significance.

Rendering my eyes artificially myopic in this way, I reduced my vision to 6/9 partly and 6/12, and found, as Mr. Fergus said, that houses, men, dogs, and objects of various kinds were still recognised as such, but certain details could not be detected. For example, a man and a dog at five hundred yards' distance were seen as one mass; a flag on a flagpole at a distance of a mile was indefinite, so that one could not tell which way the wind was blowing. Outside Dunedin Harbour I mistook a ship on the rocks for the rocks themselves. By bright ordinary daylight I should have experienced little or no difficulty in navigating. Furthermore, in a long motor run there was not the least difficulty in seeing details on the road, and there would have been no difficulty in steering the motor. At evening, however, and at night,

the matter was entirely different, and with this reduced vision motor driving would have been full of difficulty and danger by reason of the reduction of the range of vision. When, however, I lowered the vision to 6/18 partly navigation and motor driving would have been dangerous by night or day.

The experimental evidence obtained by the Expert Committee at Shoeburyness was to the effect that vision of less than 6/12 seriously affects colour perception, and that consequently 6/12 represents the minimum of vision compatible with safety. This accords with my own personal experience, with the reservation that anyone who possesses 6/6 vision will be a much safer navigator, other things being equal, than anyone who possesses 6/12 vision.

Mr. Fergus seems to draw a distinction between myopia and hyperopia, but when I have rendered my vision defective by rendering my eyes hyperopic—that is, by the wearing of concave spectacles—I have been unable to detect any practical difference in the result. In both cases one makes many failures when one's colour vision is tested by the lantern. When the aperture is small and the light a little dim, no colour can be seen at all, probably for the reason that Sir William Abney instances.

In Sir William Abney's work, dated 1913, 'Researches in Colour Vision' (p. 409), reference to similar experimental work is made The writer, a few years ago, when considering other causes than those *of deficient colour* sensation which might prevent the recognition of colour, came to the conclusion that the optical condition of the eye might be of such a nature that small discs of coloured light might be taken as colourless or not seen at all. To confirm or disprove his diagnosis he made his eye myopic and observed a ship's light from the sea-coast and also known stars, and found that with about half normal vision the ship's light at two miles was sometimes invisible or colourless, and that only stars above the fourth or fifth magnitude could make any impression on the retina.

Conclusion.

There is abundant evidence to show that a number of disasters by land and sea are attributable to defective vision. There is also good reason for thinking that a larger number of accidents have occurred which have not been reported, and, as Mr. Nettleship says, they never will be reported under existing conditions. It is clear that, so long as the present mode of lighting ships and the present method of using railway signals are continued, form vision below 6/12 is dangerous as regards its effect on colour perception, and is dangerous by reason of the limitation of the range of vision in dull light, and I am of opinion that for the purposes of safety the minimum visual requirements should be 6/9 in one eye and 6/18 in the other. A hypermetropia of two dioptres with astigmatism not exceeding ·75 D might be permitted. The colour vision should be normal and tested both with wools and lights, and there should be no ocular disease. To satisfy these requirements it is necessary that all those who go to sea or enter the railway service to earn a livelihood should be examined at

the outset of their career, since one complete ophthalmological examination at that period of life will enable the future vision of the examinee to be predicted with tolerable certainty.

It will be seen that the method adopted by the Victorian Railways would eliminate those who have a high degree of hypermetropia; but it may admit those suffering from choroiditis with contracted fields, from glaucoma, and, in fact, any eye disease which is not obvious and which has no lowered central form vision.

Stress need hardly be laid on the injustice perpetrated in allowing anyone to enter a seafaring life, to spend some years in acquiring proficiency, and then subject him to a visual examination when he makes his appearance for his first professional examination. The sensible course is obviously to insist on a complete examination when the boy first goes to sea.

Dry-Farming Investigations in the United States. By LYMAN J. BRIGGS, M.S., Ph.D.

[PLATE V.]

(Ordered, on behalf of the General Committee, to be printed *in extenso.*)

THE term 'dry-farming' is now generally applied to agricultural practice in regions where rainfall is the primary limiting factor in crop production. The determination of the tillage methods which are most efficient in the storage and conservation of moisture, and the development of varieties which are especially suited to dry-land conditions, are economic problems worthy of the best efforts of the agronomist. The most efficient methods are not always the most profitable methods, for the margin of profit in dry-farming is normally small, and the cost of tillage must always be compared with the return. Efficiency in the use of the limited rainfall is, however, the basis upon which dry-farming practice must be built.

Before taking up the discussion of dry-farming investigations in the United States, a word regarding the organisation of the Department of Agriculture in this connection may be of interest. Five offices in the Bureau of Plant Industry are devoting a large part of their energies to dry-farming problems. The Office of Dry-Land Agriculture operates over a score of experimental farms in various sections of the Great Plains. This office is concerned chiefly with the determination of the crop rotations and tillage methods which are best adapted to the various dry-farming sections. It was early recognised in the development of this work that dry-farming problems are often of an extremely local character, and that numerous experimental stations are necessary to cover the field. Each experimental farm is superintended by a trained agriculturist, usually an agricultural college graduate. These farms also afford experimental facilities for other offices engaged in dry-farming problems. The offices of Cereal Investigations, Forage Crop Investigations, and Alkali and Drought-Resistant Plant Investigations are engaged in the investigations of crops suited to

dry-land conditions; while the Office of Biophysical Investigations, in co-operation with the above-named offices, is concerned with the study of the influence of various tillage methods on the absorption and retention of rainfall, the water requirement of crops under field conditions, and the influence of climatic conditions on the growth of dry-land crops. Over 50,000*l.* is now appropriated annually by Congress for the support of the dry-land work. In addition to this, several of the States are also conducting dry-farming investigations on an extensive scale, either independently or in co-operation with the Government. The field of investigation is so extensive that the present paper will be confined largely to the biophysical phases of the work.

Dry-Farming Areas in the United States.

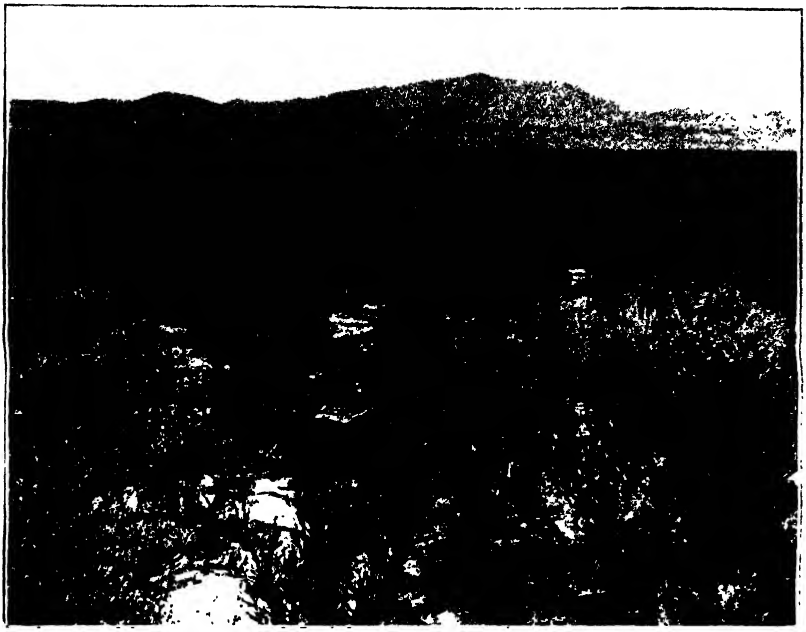
Two great dry-farming areas occur in the United States. One, the Intermountain area, lies between the Rocky Mountains on the east and the Sierra Nevada Mountains on the west. It is essentially a region of winter and spring rainfall. The other, the Great Plains area, extends from the Canadian boundary along the eastern side of the Rocky Mountains nearly to the Mexican boundary, and embraces over 200,000 square miles of land whose productivity is limited by the rainfall. This area, in contrast to the other, is a region of summer rainfall.

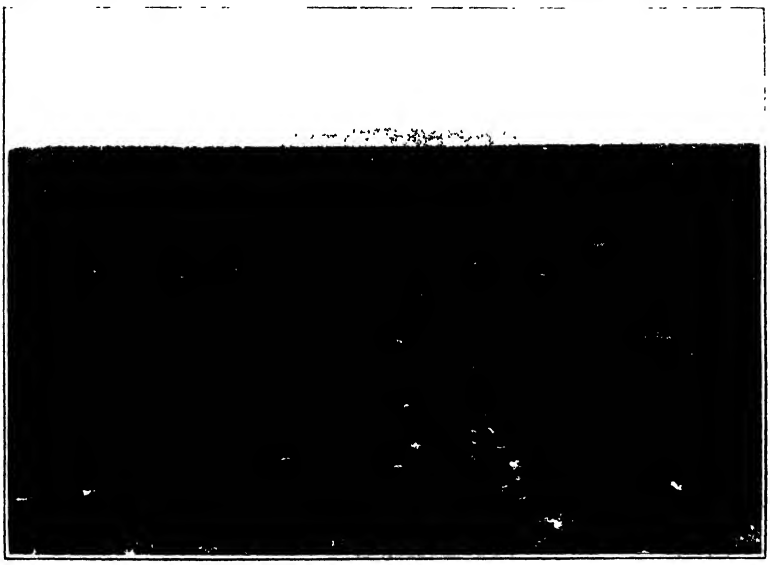
These two great areas differ greatly in their physiographic features and in their native plant cover. The Intermountain district is broken into numerous valleys, and the vegetation consists mainly of shrubby perennial plants, such as the sage-brush (*Artemisia tridentata*) (Plate V.) and a salt-bush (*Atriplex confertifolia*). The size and character of this vegetation affords a good index of the productivity of the land.[1] The larger the sage-brush the greater the water-supply and the better the farm. The soils occupied by salt-bush, on the other hand, are apt to be so saline in character as to be unsuited to dry-farming.

In the Great Plains no trees or shrubs are found except along the water-courses, while the gently undulating, grass-covered plain stretches unbroken to the horizon save for the buildings of the settlers. Much of this country is covered with buffalo grass (*Buchloë dactyloides*) and grama grass (*Bouteloua oligostachya*) (Plate V.), while farther to the east, where the rainfall is somewhat heavier, the taller bunch grass (*Andropogon scoparius*) and wire grass (*Aristida longiseta*) make their appearance.[2] This striking difference in the vegetation, characterised by the shrubby plants in the Intermountain districts and by grasses on the plains, reflects the difference in the distribution of the annual rainfall, which has had a marked effect upon the dry-farming development of the two sections.

[1] 'Indicator Significance of Vegetation in Tooele Valley, Utah,' Kearney, Briggs, Shantz, McLane, and Piemeissel, *Journal of Agricultural Research*, United States Department of Agriculture, 1, p. 365, 1914.

[2] Shantz, H. L., *Natural Vegetation as an Indicator of the Capabilities of Land for Crop Production in the Great Plains Area*, U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 201, 1911.





Showing the native sage-brush vegetation on virgin land in the Intermountain district (above), and the short-grass vegetation of the virgin Great Plains (below). The Intermountain district has a winter rainfall and the Great Plains a summer rainfall. (Photographed by H. L. Shantz.)

Illustrating the Report on Dry-Farming Investigations in the United States.

[*To face page* 261.

Rainfall.

It has become customary to use the average annual rainfall as a measure of the relative value of different areas for dry-farming purposes. Since the water-supply is usually the primary limiting factor, the annual rainfall must of course be emphasised. All who are engaged in dry-farming investigations recognise, however, the severe limitations of this classification. The seasonal distribution and the character of the rainfall—whether torrential or in the form of numerous light showers, or occurring as steady, soaking-rains—are often more important than the total annual rainfall in determining the productivity of a dry-farming region. The uncertainty of the rainfall should also be considered whenever sufficient statistical evidence is available.

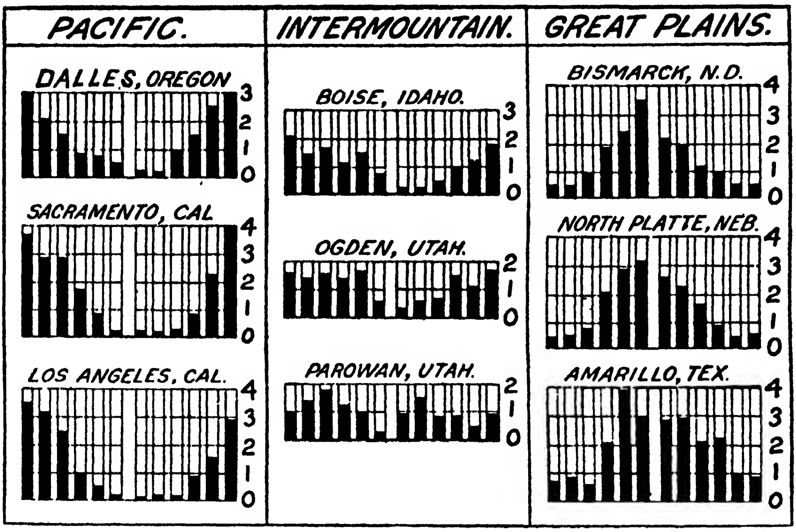


FIG. 1.- Chart showing the monthly distribution of the rainfall at representative stations in the Great Plains, Intermountain, and Pacific coast regions. The length of the black lines in each diagram represents the monthly precipitation at that place, beginning with January on the left. The scale in inches given on the right of each diagram can be used to find the actual amount of the monthly rainfall. For example, the average monthly rainfall at Bismarck, N. Dak., for June is seen to be 3½ inches, while for July it is only a little more than 2 inches. It will be noted that in the Pacific coast region the rain comes principally at the beginning and end of the year, that is, in the winter; in the Intermountain districts during the winter and spring months; and in the Great Plains during the summer months.

Rainfall is not the only factor of importance, however. We shall refer later to the desirability of knowing the seasonal evaporation as measured from freely exposed tanks, which affords a summation of those factors which determine the rate of transpiration. The maximum temperatures and the wind velocity are also important factors. For an adequate comparison of widely separated dry-farming areas, a knowledge at least of the annual rainfall, its seasonal distribution, the

seasonal evaporation, and the depth and character of the soil appears to be indispensable.

Reference has already been made to the striking difference in the monthly distribution of the rainfall in the Great Plains as compared with the Intermountain districts. This difference is illustrated in fig. 1, which shows the monthly distribution of rainfall at representative stations in each area. Three Pacific Slope stations with a distinctly winter type of rainfall are also included. In this latter region, owing to the mildness of the climate, an annual crop of wheat is grown during the winter months either for grain or hay.

Grain-farming under the alternating fallow and cropping system has been satisfactorily established in Utah, where the annual rainfall is 13 inches or more. In the southern part of the State of Washington, where the conditions are unusually favourable, land with an annual rainfall as low as 10 inches is used for growing winter wheat by the summer-fallow method,[3] but the returns are uncertain. When the annual rainfall is reduced to 8·5 inches the crop will barely return the cost of production.

The rainfall required when the rain comes chiefly in the summer is higher than for winter rainfall. This appears to be due to the greater evaporation-loss from the fallow when wet frequently by summer rains. In the Great Plains, where a summer rainfall prevails, dry-farming is not successfully conducted on an annual rainfall less than 14 inches, and this minimum is still higher in the southern part of the area, due, as we shall see, to the higher rate of evaporation.

Evaporation.

The evaporation-rate may fairly be considered as ranking next in importance to the annual rainfall in determining the dry-farming possibilities of a region. The evaporation from a free-water surface represents a summation of the intensity of solar radiation, temperature, saturation-deficit, and wind velocity, all of which enter also into the determination of the transpiration-rate of the growing crop, though not necessarily in the same proportion as in free evaporation. Evaporation has been measured daily during the summer months at each of the experimental farms located in the dry-farming sections. Tanks 6 or 8 feet in diameter and 2 feet deep are used, the tanks being sunk in the ground to within four inches at the top. The free-water surface is maintained at ground-level, *i.e.*, about 4 inches from the top of the tank. Observations are now available for seven years at the stations first established. The observations are limited to the six months from April to September inclusive, since freezing weather is encountered at the stations during most of the remaining months. The average seasonal (April to September inclusive) evaporation in inches for each station, together with its location, is shown on the accompanying map (fig. 2). The evaporation increases rapidly as one proceeds southward in the Great Plains; the evaporation in Northern Texas, for example, is 54 inches, compared with 31 inches

[3] Briggs, L. J., and Belz, J. O., *Dry Farming in relation to Rainfall and Evaporation*, U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 188, p. 25.

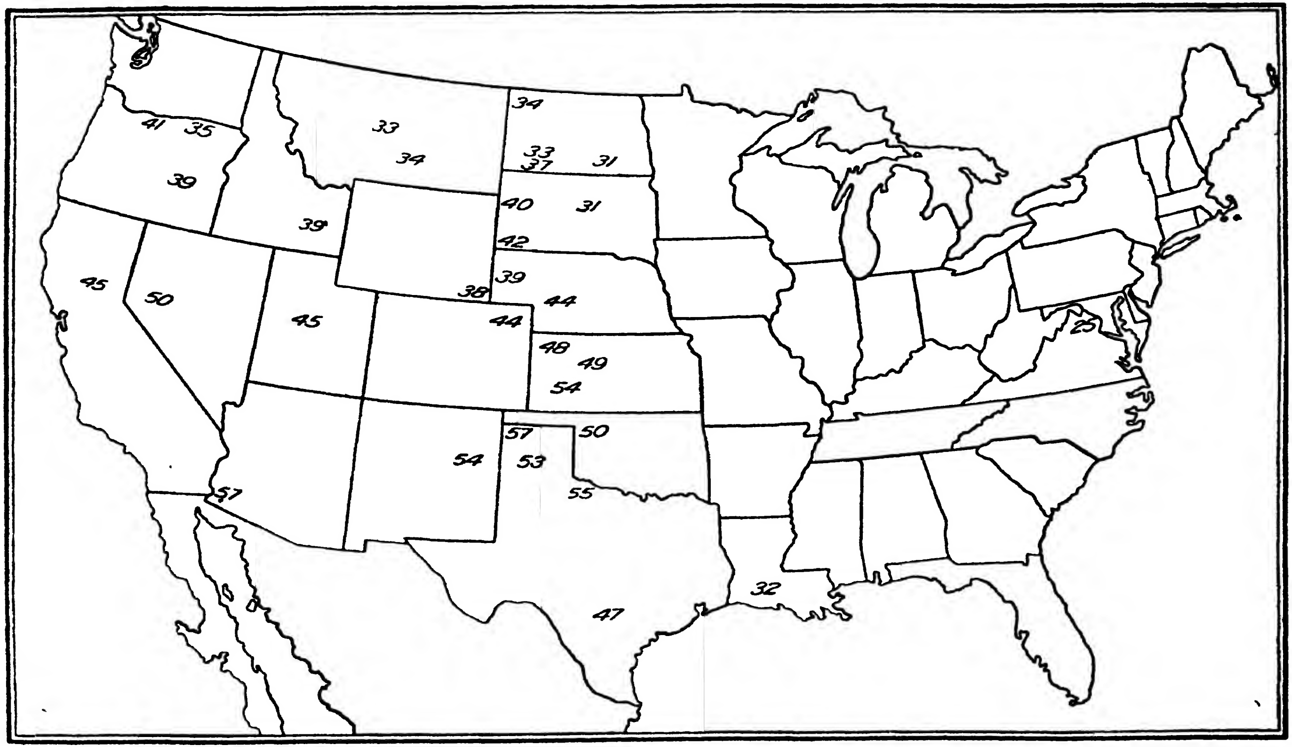


FIG. 2.—Map showing stations at which evaporation measurements are being made by the Office of Biophysical Investigations. The figures show the evaporation in inches during the six summer months (April to September inclusive). It will be seen the evaporation in the southern part of the Great Plains is nearly twice that in the northern part.

in the central part of North Dakota. Such differences have a profound influence upon the water-requirement of plants.

Shantz [4] has shown that under practically uniform soil conditions a pure short-grass formation is found in Northern Texas with an annual rainfall of about 21 inches; in Eastern Colorado with an annual rainfall of about 17 inches; and in Montana with an annual rainfall of approximately 14 inches. The region throughout has a summer rainfall. The same plant formation then requires 50 per cent. more rainfall in Northern Texas than in Montana. The explanation of this is to be found in the difference in the evaporation-rate in the two sections. Reference to fig. 2 will show that the evaporation in Northern Texas is approximately 60 per cent. higher than in Central Montana. A similar comparison between Northern Texas and North-Eastern Colorado shows that short-grass requires about approximately 27 per cent. more rainfall in Northern Texas, where the evaporation is 23 per cent. higher than in North-Eastern Colorado. The effectiveness of rainfall depends of course upon its penetration into the soil, so that any relationship which may be developed between evaporation and precipitation will necessarily be an approximate one. The above figures indicate, however, a rather close parallelism between the evaporation and the rainfall required to maintain a given plant formation, and emphasise the necessity of knowing the evaporation as well as the rainfall in judging the dry-farming possibilities of a region.[5]

A direct relationship between evaporation and water-requirement—*i.e.*, the pounds of water required by a plant in the production of a pound of dry matter—is shown in the following measurements by Briggs and Shantz of the water-requirement of the same strain of alfalfa when grown in different parts of the Great Plains (Table I.).

TABLE I.—*Water-requirement of Grimm alfalfa (second cutting) at different Stations in the Great Plains,* 1912.

Location	Growth period	Days	Water-requirement (to produce 1 lb. dry matter)		Evap. in inches	Daily Evap. in inches	Ratio of W.-R. to Daily Evap.
			lb.	oz.			
Williston, N.D.	July 29–Sept. 16	47	518	12	7·5	0·159	33
Newell, S.D.	Aug. 9–Sept. 24	46	630	8	8·6	0·187	34
Akron, Col.	July 26–Sept. 6	42	853	13	9·5	0·226	38
Dalhart, Tex.	July 26–Aug. 31	36	1005	8	11·0	0·306	34

It will be seen that the water-requirement increases steadily as one proceeds southward through the Great Plains, being twice as great in Northern Texas as in North Dakota. The daily evaporation

[4] Shantz, H. L., *Natural Vegetation as an Indicator of the Capabilities of Land for Crop Production in the Great Plains Area,* U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 201, 1911, p. 12.

[5] Briggs, L. J., and Belz, J. O., Bureau of Plant Industry, Bulletin 188, 1911, p. 20.

also increases in a corresponding manner, so that the ratio of the water-requirement to the daily evaporation is approximately constant. Montgomery and Kiesselbach[6] have shown that maize grown in a dry house and in a humid house varied in its water-requirement exactly in proportion to the relative evaporation-rates in the two houses.

The water-requirement is not, however, always proportional to the evaporation. Other factors such as temperature may have a profound influence in determining the development of the plant. This may be illustrated by comparing the water-requirement of wheat and sorghum in Colorado and in Northern Texas (Table II.).[7] When the difference in evaporation is considered, sorghum is seen to have made a more efficient use of its water-supply in Texas than in Colorado, while the reverse is true in the case of wheat.

TABLE II.—*Comparison of the Relative Evaporation and of the Relative Water-requirement in the Great Plains in 1910 and 1911.*

Station	Year	Crop	Growing period	Evaporation		Water-requirement	
				Actual	Relative	Actual	Relative
Akron, Colo.	1910	wheat	April 18–Aug. 2	27·7	100	664	100
Amarillo, Tex.			April 5–July 19	34·0	122	853	128
Akron, Colo.	1910	sorghum	May 25–Sept. 28	33·0	100	356	100
Amarillo, Tex.			May 10–Aug. 28	37·7	114	359	101
Akron, Colo.	1911	wheat	May 13–Aug. 2	24·8	100	468	100
Dalhart, Tex.			April 25–July 18	28·5	115	673	143
Akron, Colo.	1911	sorghum	May 12–Sept. 4	35·0	100	298	100
Dalhart, Tex.			May 14–Sept. 12	41·9	120	313	105

Influence of the Distribution of Rainfall on Farm Practice.

The different distribution of the rainfall in the Intermountain district and the Great Plains has led to interesting differences in the farm practice of these regions.

Spring wheat is not a successful crop in the Intermountain district for two reasons: (1) The land cannot be fitted for sowing until late in the season, owing to the spring rains; and (2) the driest part of the season occurs when the spring wheat crop is maturing. A large acreage of winter wheat is, however, grown. In fact, the dry-farming activities of this section are devoted almost wholly to the growing of winter wheat. The stubble is not usually ploughed until spring, the land being very dry and hard in the fall. The stubble also keeps the winter snows from drifting and thus holds the precipitation on the land. As soon as the

[6] *Studies in the Water-requirement of Corn,* Nebraska Agricultural Experiment Station, Bulletin 128, 1912.

[7] Briggs, L. J., and Shantz, H. L., *Water-requirement of Plants; I.*, U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 284. p. 45

spring rains have ceased, the stubble and the early growth of weeds are turned under, and the land is kept fallow until the following autumn. The low rainfall during the summer makes it possible to destroy the weed-growth and maintain an efficient surface-mulch at a comparatively low cost. In the autumn, wheat is again sown. The crop makes a good part of its growth while the temperature is cool and the evaporation low, and in addition to the stored moisture has the advantage of the seasonal precipitation during its growth period.

One serious difficulty in dry-farming operations in regions of winter rainfall occurs in connection with the seeding of winter wheat on fallow land. The surface-mulch of the fallow is often dust-dry in the fall to a depth of 4 inches or more. If the farmer drills his grain in the dust, the seed remains inert until a rain occurs. If the first rain is insufficient in amount to soak through the dry mulch to the damp soil below, the seeds germinate, but the rootlets of the seedling plants do not reach the stored moisture below the intervening dry layer, and the plants soon die. On this account, farmers usually wait for fall rains before sowing wheat. If the seeding is thereby delayed until late in the fall, and freezing weather follows, the young plants are injured and weakened. And if this is followed by an 'open winter,' so that the wheat plants are not protected by a covering of snow, 'winter killing' is often very severe, and the crop is practically a failure.

Drilling the wheat to a depth sufficient to place the seed in moist soil would appear to be a possible solution of this problem, but this is often found impracticable, and the seedling plants have great difficulty in forcing their leaves to the surface. It is possible that a solution of the difficulty may be found in a seed-drill which has recently been developed, which throws the dry surface-soil in ridges, and plants the grain in moist soil at moderate depths in the intervening furrows. This plan is not practicable in windy regions, for the furrows would soon fill with dry soil.

In striking contrast with Intermountain practice, spring wheat is grown extensively in the Great Plains, especially in the central and northern part. The spring-sown crop escapes the dry fall and all danger from winter-killing, while the land, having been recently worked, is in better condition to absorb the summer rainfall. Intertilled crops are also grown to a much greater extent than in the Intermountain district, maize being especially popular in the northern part of the Great Plains, and the non-saccharine sorghums (milo, kafir, sorgo) in the southern part. The intertilled crop has in many sections largely taken the place of fallow, spring wheat now being extensively grown on disked corn-land.

Fallow is used extensively in the Great Plains, but the experiments by the Office of Dry-Land Agriculture, under the direction of E. C. Chilcott,[8] have shown that alternate cropping and summer tillage in many sections is less profitable than simple three-year rotations, especially those in which spring wheat is grown on disked corn-land, and even less profitable than continuous cropping. Summer tillage is not

[8] *A Study of Crop Rotations and Cultivation Methods for the Great Plains Area*, U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 187, p. 8, 1910.

so well adapted to a summer rainfall as to a winter precipitation, for the summer rains repeatedly pack the mulch, which necessitates frequent cultivation to keep the land in a receptive condition and to destroy the weeds which spring up after each rain. Summer tillage, however, affords some insurance against total loss of a crop during a dry season, which means disaster to the farmer with work-animals and cows to feed, and this element of insurance will doubtless always be a factor with the small farmer, even if summer tillage does not give the greatest returns.

Owing to the frequent high winds in the Plains, the blowing of the mulch on summer-tilled land sometimes becomes a serious problem. It is highly important in fallowing the Plains to keep the surface of the soil in a rough condition; in other words, to maintain a clod-mulch on the fallow rather than a dust-mulch, a practice which is also advantageous in the absorption of rainfall. On lands subject to blowing, the practice of cultivating in strips is sometimes followed. The strips are laid out at right angles to the prevailing winds, and alternating strips are planted to grain or an intertilled crop. Jardine[9] has recently emphasised the value of the lister in checking blowing in extreme cases. This implement opens a broad shallow furrow, throwing the dirt on both sides. Groups of two or three furrows each are listed at distances of from five to twenty rods across the field at right angles to the wind. The lister tends to form clods, while the disk harrow, except in moist ground, tends to pulverise the soil, and this must always be avoided in soils subject to blowing.

Depth of Root System in relation to Storage of Soil Moisture.

The great depth to which the roots of many of our cultivated plants extend has a very important bearing on the practicability of storing moisture in the soil. Burr[10] has found that oats, spring wheat, barley, and corn growing on the loess soils of Eastern Nebraska use the water to a depth of 4 feet or more, while winter wheat feeds to a depth of 6 or 7 feet. Excavations made in winter-wheat plats in Utah showed the root system to extend to a depth of 7 feet.[11]

In a soil which can store 6 per cent. of 'growth water,' there would be available in a section 6 feet in depth 600 tons of water per acre, or enough for the production of thirteen bushels of wheat in the central Great Plains.[12] For a root penetration of 4 feet, this amount would be reduced approximately one-third.

When the system of alternate cropping and fallowing is employed, water seldom moves below the zone occupied by the roots of the wheat plant. This has taken place, however, at the Dickinson experimental farm in western North Dakota. The water which moves below the feeding zone is practically lost to the plant, and remains undisturbed

[9] *Jour. Am. Soc. Agron.* 5, 213, 1913.
[10] Research Bulletin No. 5, Nebraska Experiment Station, 1914.
[11] Merrill, Bulletin 112, Utah Experiment Station, 1910.
[12] Briggs and Shantz, 'Relative Water-requirement of Plants,' *Jour. Agricultural Research*, U.S. Department of Agriculture, 3, 1, 1914.

from year to year. An argument often advanced in favour of deep-ploughing is that the depth of root penetration is thereby increased. The futility of this argument so far as dry-farm soils are concerned becomes evident when it is realised that the normal penetration of roots in the Intermountain and Great Plains soils is far below any depth that could possibly be reached with the plough. Deep ploughing may possibly increase the absorption-rate of rainfall when the precipitation-rate is so high as to saturate the surface soil temporarily, but this effect can also be secured by leaving the surface rough and corrugated when cultivating. Many of the field tests of the Office of Dry-Land Agriculture have failed to show any increase in yield from deep ploughing, an operation which means an added expense to an industry in which economy in labour must be rigidly exercised to show a reasonable profit.

Loss of Water from Weeds.

A relatively small proportion of the total annual rainfall is conserved in the fallow. The maximum quantity of stored moisture available for the crop seldom exceeds 4 inches of rainfall in sections where the annual rainfall ranges from 13 to 18 inches. This low efficiency is due in part to loss from run-off, but mainly to surface evaporation and to loss through the transpiration of weeds. Numerous measurements have shown that a rainfall of less than one-half-inch does not contribute to the permanent store of moisture in the soil unless the surface soil is already wet from previous rains. If the rainfall penetrates the soil below a depth of 6 inches, its rate of loss due to evaporation is low. But if the fallow is weedy, the stored water is lost through the transpiration of the plants almost as rapidly as if the moist subsoil were freely exposed to the air. The water-requirement of weeds is fully as high as some of our most valuable crop plants. For example, pigweed (*Amaranthus retroflexus*), tumble-weed (*Amaranthus græcizans*), and Russian thistle (*Salsola pestifer*) have a water requirement as high as the millets and sorghums, while sunflower (*Helianthus petiolarus*) and lamb's quarters (*Chenepodium album*) rank higher than many of the legumes.[13] The dry-farmer can, therefore, produce a valuable forage or grain crop with no greater expenditure of water per pound of dry matter than is lost through the weeds on his fallow.

Determinations by W. W. Burr[14] in Nebraska, R. W. Edwards[15] and J. G. Lill[15] in Kansas, and C. B. Burmeister[15] in Texas, all unite in showing that the evaporation loss from land from which the weeds are sliced off with a hoe is but little greater than from cultivated plants. In other words, cultivation is effective in conserving water mainly through the destruction of weeds rather than in the reduction of surface evaporation. This is well illustrated by Lill's measurements at Garden City, Kansas, as shown in fig 3. The

[13] Briggs and Shantz, *Jour. Agricultural Research*, U.S. Department of Agriculture, 3, 60, 1914.

[14] Research Bulletin No. 5, Nebraska Experiment Station, p. 61, 1914. In co-operation with the Office of Dry-Land Agriculture and Biophysical Investigations.

[15] Office of Dry-Land Agriculture in co operation with the Office of Biophysical Investigations.

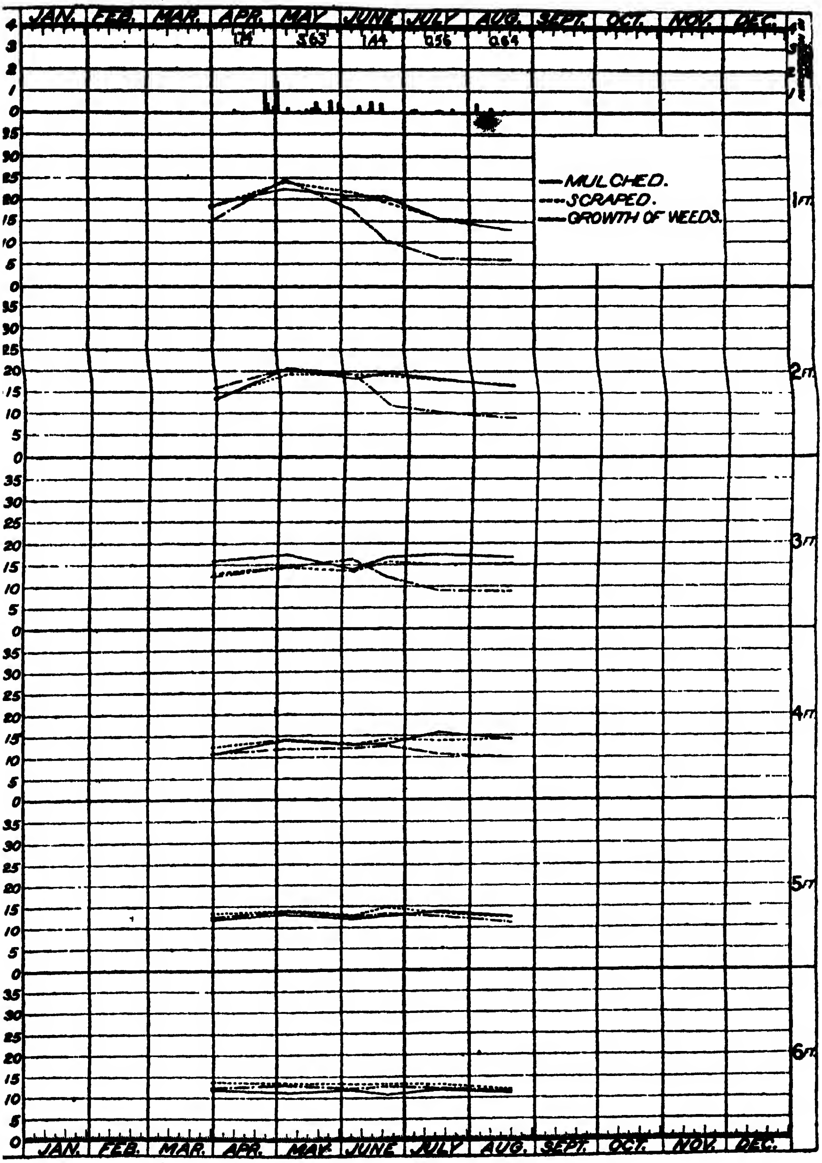


FIG. 3.—Loss of moisture from a mulched plat in comparison with a plat the surface of which has been scraped with a hoe to cut the weeds, and with a plat on which the weeds were allowed to grow. It will be seen that the mulched plat and the scraped plat differ little in effectiveness in conserving water, while the weeds reduce the moisture content to a depth of 3 feet.

moisture content of the mulched plat did not differ markedly from the plat on which the weeds were kept sliced off with a sharp hoe; while the plat on which the weeds were allowed to grow was dried out to a depth of 3 feet.

A striking example of the loss of moisture from weeds is also shown in experiments by P. V. Cardon, conducted at Nephi, Utah.[16] Winter wheat was grown on four plats by the summer fallow system, one-half the plats being in wheat each year. Two plats were fall-ploughed each year, and during the following summer, one plat was cultivated to destroy the weeds, while the other was left untouched except to clip the weeds in time to prevent the seeds maturing. In the autumn both plats were sown to winter wheat. The experiment was conducted for four years, and during this time the yield from the cultivated plat averaged four bushels more per acre than from the weedy plat.

The loss of moisture in these plats as the season advanced, due to the demand made by the weeds, is illustrated in the accompanying graphs, fig. 4. That this loss is primarily due to the weed cover and not to direct evaporation is supported by the fact that in other experiments at this station spring-ploughed uncultivated fallow on which the weed-growth was slight was practically as effective as cultivated fallow in conserving moisture. The average moisture content (6 feet in depth) of the weedy Nephi plat was at the time of the spring sampling 0·8 *per cent.* below the *cultivated plat*, and at the time of the *Fall sampling* 4·5 per cent. below the cultivated plat. This loss in moisture during the summer is equivalent to 3·5 inches of rainfall *stored in the soil*. This amount of water is sufficient, according to the water-requirement measurements of Briggs and Shantz,[17] to produce ten bushels of wheat per acre at Akron, Colorado, where the evaporation is the same as at Nephi. In 1911 the actual increase in yield of the cultivated plat over the weedy plat was eleven bushels per acre. During the other years the yield was reduced by winter killing, so that the water-supply was not the primary factor in determining production. Surely no more convincing proof is needed of the necessity of keeping fallow land free from weeds in regions where the moisture supply is of primary importance.

Growth-water.

It has long been known that a part of the soil-moisture is held so tenaciously that it is not available for the growth of plants. Sachs in 1859 appears to have been the first to recognise that the percentage of non-available moisture varies greatly with the type of soil. This is a matter of fundamental importance in the interpretation of soil-moisture observations, for the water unavailable for growth ranges from 1 per cent. or less in sand to 30 per cent. or more in the heaviest

[16] Office of Cereal Investigations in Co-operation with the Office of Biophysical Investigations. See *Tillage and Rotation Experiments at the Nephi sub-station, Utah,* U.S. Department of Agriculture, Bulletin 157, 1914.

[17] Briggs, L. J., and Shantz, H. L., 'Relative Water-requirement of Plants,' *Journal of Agricultural Research,* U.S. Department of Agriculture, 3, 1, 1914.

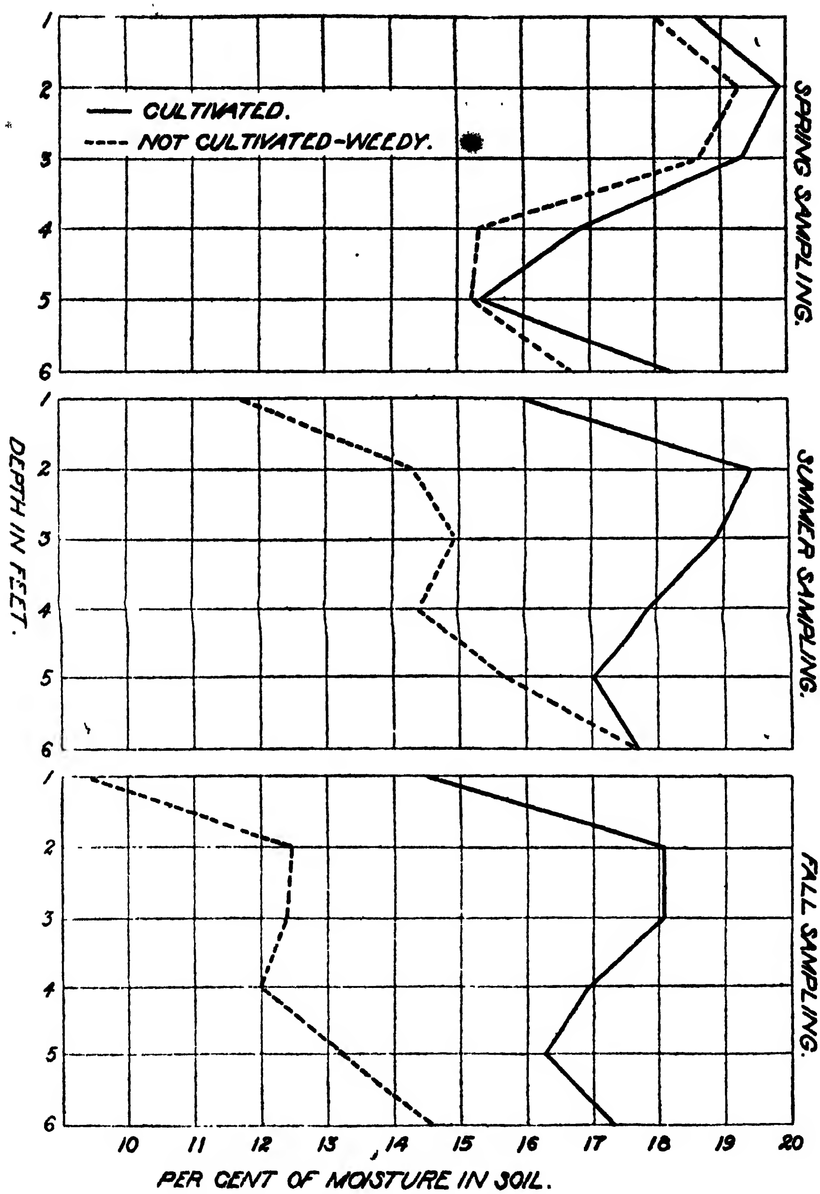


FIG. 4.—Loss of water from cultivated and weedy plats at Nephi, Utah, as the season advances.

types of clay.[18] Obviously, then, the percentage of water in the soil that is available for the growth of plants, or the 'growth-water' as Fuller[19] has termed it, cannot be determined until this unavailable residue is known.

Alway[20] has used the hygroscopic coefficient, *i.e.*, the percentage amount of water that a dry soil absorbs on exposure to a saturated atmosphere, to represent the unavailable portion. Briggs and Shantz[21] have measured the moisture-content at which plants undergo permanent wilting when growing in a limited soil mass, protected from surface evaporation. By permanent wilting is meant a condition from which the plants cannot recover when exposed to a saturated atmosphere.[22] The percentage of moisture remaining in the soil under such conditions has been termed the 'wilting coefficient' of that particular soil, and has been found to vary slightly with the kind of plant used as an indicator. The 'wilting coefficient' in connection with a total moisture determination provides a means for calculating the 'growth-water,' the latter being the surplus above the wilting coefficient. By the aid of such determinations it is possible to calculate the amount of stored growth-water—the bank-balance, so to speak, in the water account, against which the crop may draw.

It is not necessary always to measure the wilting coefficient directly, since it can be calculated from other physical properties of soils that can be more readily measured. Thus the moisture equivalent, hygroscopic coefficient, and mechanical composition have all been shown to bear a linear relationship to the wilting coefficient.[23] Of these indirect methods, that based on the moisture equivalent[24] is the most rapid and satisfactory. The latter represents the percentage of moisture remaining in the soil when brought into equilibrium with a centrifugal force 1,000 times that of gravity. The wilting coefficient is approximately one-half the moisture equivalent.

Where a small grain-crop has extended its root-system to a depth of 4 feet or more, the moisture-content of the second and third feet is sometimes reduced below the wilting coefficient. This is practically sure to occur if the crop is suffering for water, for plants are able to reduce the moisture-content far below the wilting coefficient while in a wilted condition, or during the ripening process. But it appears also to take place while the crop is still growing, provided the root-system is in contact with growth-water in some other part of the soil mass.[25]

[18] Briggs, L. J., and Shantz, H. L., *The Wilting Coefficient for Different Plants and its Indirect Determination*, U.S. Department of Agriculture, Bureau of Plant Industry, Bulletin 230, 1912, pp. 56–59.

[19] *Botanical Gazette*, **53**, p. 513, 1912.

[20] *Journal of Agricultural Science*, **2**, 1908, p. 334. [21] *Op. cit.*

[22] As the plant approaches a wilted condition its transpiration is reduced. Furthermore, as soon as wilting occurs it is necessary to transfer the plant to a saturated atmosphere, in order to determine whether the observed wilting is temporary or permanent. Consequently during the final stages of a wilting coefficient determination the transpiration rate is greatly reduced.

[23] Briggs and Shantz, *op. cit.*

[24] Briggs and McLane, *Jour. Am. Soc. Agron.* **2**, 1910, p. 138.

[25] Briggs, L. J., and Shantz, H. L., 'Application of Wilting Coefficient Determinations to Agronomic Investigations,' *Jour. Am. Soc. Agron.* **3**, 1911, p. 250.

SPRING WHEAT. AKRON, COLORADO, 1911. FALLOW. AKRON, COLORADO, 1912.

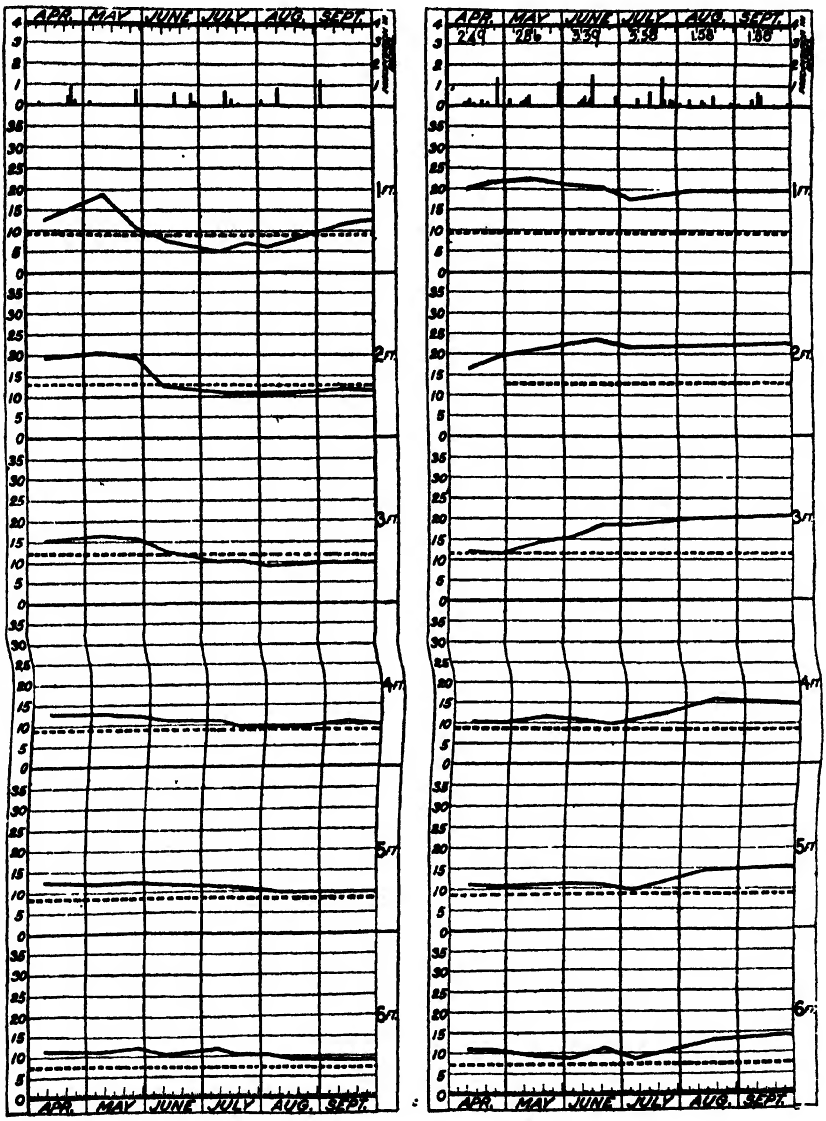


FIG. 5.—Moisture conditions in spring wheat and fallow plats at Akron, Colorado, to a depth of 6 feet. The dotted lines represent the wilting coefficient for each foot-section.

In other words, where the root-system is already established the crop is able to reduce the moisture-content below the wilting coefficient, and can use this to supplement the growth-water that it is drawing from lower levels. (*See* fig. 5, 1911.) On the other hand, crop-plants

show no tendency to send new roots into soil in which the moisture-content is reduced to the wilting coefficient. (*See* fig. 6, 1911.)

An example of the application of the wilting coefficient to the interpretation of moisture determinations is shown in the accompanying measurements by W. M. Osborne [26] at Akron, Colorado (fig. 5). The change in moisture during the season in each foot-section to a depth of 6 feet is shown graphically by the solid lines. The dotted lines represent the wilting coefficient for each foot-section. The first chart (1911) represents the moisture conditions under a crop of spring wheat during a dry season, the crop being practically a failure. It will be seen that in the spring there was available moisture in small amounts to a depth of 6 feet, the greater part being in the upper 3 feet. The crop had removed the growth-water from the first foot by June 1; from the second and third feet by June 15; from the fourth foot by July 15; while the fifth and sixth feet still contained a limited amount of growth-water at harvest time, although the moisture had been reduced in each case.

The second chart (1912) shows the moisture conditions in the same plat during the next summer while the land was in fallow. At the time the spring samples were taken the moisture-content of the surface foot of soil was practically up to the field-carrying capacity of *this soil.* With the advent of the seasonal rains the surface foot began to deliver to the section below. It will be noted that the change in moisture-content does not take place simultaneously through the soil-mass, but is progressive from foot to foot, each section delivering water to the section below as it rises to its field-carrying capacity. When the moisture supply is below a certain percentage, dependent upon the soil in question, capillary adjustment in that soil is very slow. Plants in order to avail themselves of all the growth-water must consequently develop a root-system which permeates the soil-mass from which water is being drawn. In other words, when the moisture supply is limited the capillary distribution becomes so slow as to be effective only through very small distances. Plants having a coarse root-system, such as maize, when used as indicator-plants, might be expected to give a somewhat higher wilting coefficient than plants with fine root-systems like the small grains, and this has been observed to be the case.[27]

The first chart in fig. 6 represents the moisture conditions as measured by J. C. Thysell [28] in a barley plat at Dickinson, North Dakota, during the dry season of 1911. This plat is normally seeded to barley each year. Inspection of the chart will show that at the beginning of the season the moisture-content of the second and third feet was at the wilting coefficient, to which it had been reduced by the preceding crop. A good supply of growth-water was present in the fourth, fifth, and sixth feet of the soil, but the roots were unable

[26] Office of Dry-Land Agriculture in Co-operation with the Office of Biophysical Investigations.

[27] Briggs and Shantz, *op. cit.*

[28] Office of Dry-Land Agriculture in Co-operation with the Office of Biophysical Investigations.

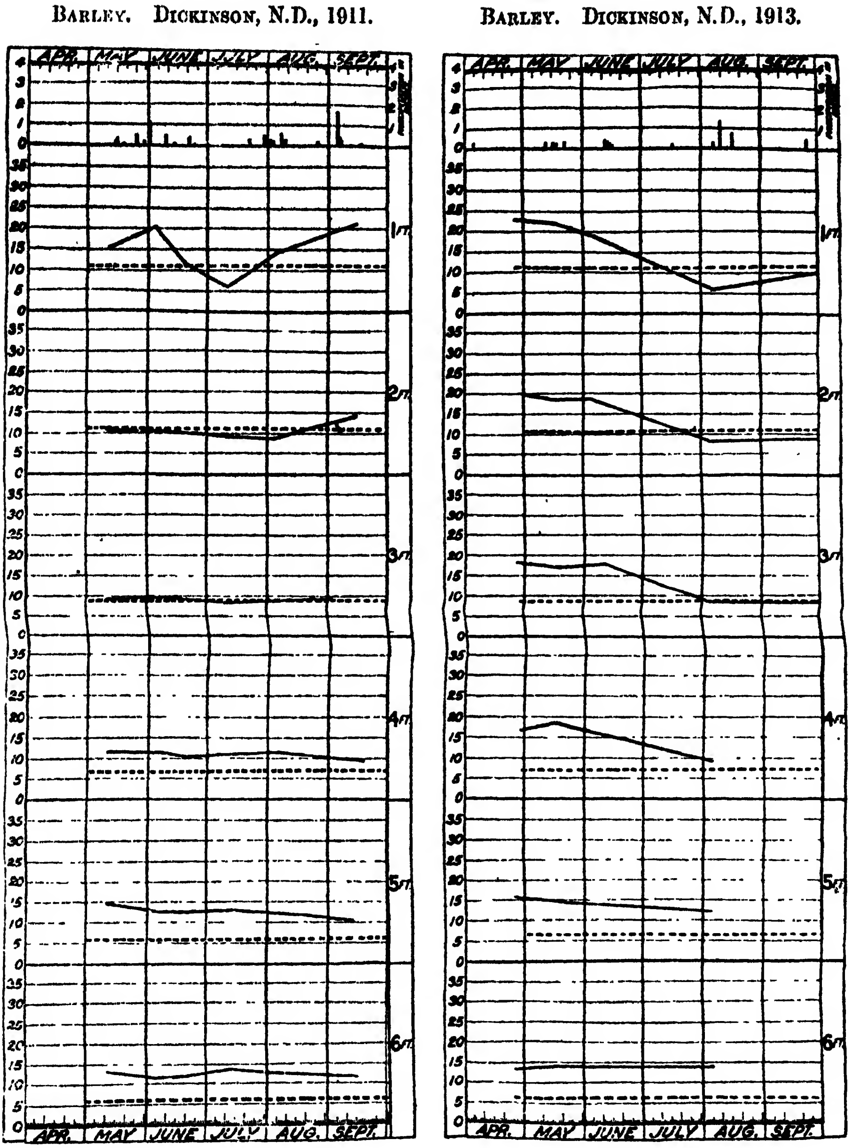


FIG. 6.—Moisture conditions in a barley plat at Dickinson, North Dakota. The dotted lines represent the wilting coefficient for each foot-section.

to penetrate the intervening dry layer, and the crop was a failure. In 1912 the crop was destroyed by hail, so that the plat was virtually in fallow during this season. The rainfall in 1912 was ample and the soil was well supplied with water in the spring of 1913, as shown in the second part of the chart. During this year a heavy crop of barley was grown, which was produced in part with water present in

the soil in 1911, but unavailable to the 1911 crop because the intervening soil was reduced to the wilting coefficient before the root system was established. It would be difficult to interpret these moisture conditions without the aid of the wilting coefficient determinations, especially where the moisture-retentivity of the soil and subsoil is not the same, as in the case of the Dickinson soils.

The growth-water content at seedtime and harvest in two plats at Akron, Colorado, is shown graphically in fig. 7 for six years. These plats form part of the cultural experiments of the Office of Dry-Land Agriculture, and are continuously cropped to spring wheat, A being spring-ploughed and B fall-ploughed. The width of the shaded portion in each foot-section shows the amount of growth-water. It will be noted that the growth-water was in every instance practically exhausted at harvest-time, with the exception of the surface-foot, which in some instances had been moistened by rains near the harvest period. It also appears that at this station the time of ploughing has little influence on the soil moisture-content.

Maintenance of the Fertility of the Dry-Farm.

The maintenance of fertility under a system of continuous grain-farming, such as is practised in many dry-farming sections, bids fair to become a more and more serious problem as the years advance. The period of cultivation of much of the dry-farm land has been so short as to afford no information on this point. In any event, it is hardly a problem that can be taken up with the man who breaks the virgin land. His first concern is for bread, and his chief desire is to draw upon the resources of his land to its fullest capacity. It is only after a marked decrease in production has occurred that he will listen to measures designed to maintain the fertility of the soil. Happily, grain-farming as practised on some of the oldest dry-farms in Utah does not yet appear to have diminished the productiveness of the soil. This is doubtless due in part at least to the fact that the wheat has been cut with a header (or more recently with a combined harvester), which leaves most of the straw on the land. Stewart and Hirst [29] have found that the humus and nitrogen content of the surface soil of the wheat lands farmed for ten years or more has not fallen below that of adjacent virgin soils. In an earlier investigation, Stewart [30] found that the oldest wheat lands in Utah, under cultivation for fourteen to forty-one years, either continuously or by summer-fallowing methods, had showed no loss in humus or nitrogen in the surface-foot. The second foot of the cultivated soils showed, however, a slightly lower nitrogen-content than the virgin land. The yield also appears to have been maintained.

A wanton waste of organic matter occurs in many dry-farming sections in the northern Great Plains and in California. The stubble is burned to make the ploughing easier and to destroy weed-seeds, and the straw-stacks are burned in the field because they are in the path of the ploughs. As the ploughing-season approaches, the horizon is

[29] *Jour. Am. Soc. Agron.* 6, 49, 1914.
[30] Utah Experiment Station, Bulletin 109, 1910.

often lighted at night in every direction by the flames of the burning stacks. Even where the straw alone has been removed, grain-farming in the Great Plains has resulted in a marked decrease in the nitrogen and humus of the soil. Alway[31] has shown that the cultivation of the loess soils of Nebraska has been accompanied by a marked reduction in nitrates, total organic matter, and humus. He attributes

AVAILABLE SPRING AND HARVEST MOISTURE CONTENT. AKRON, COLORADO.

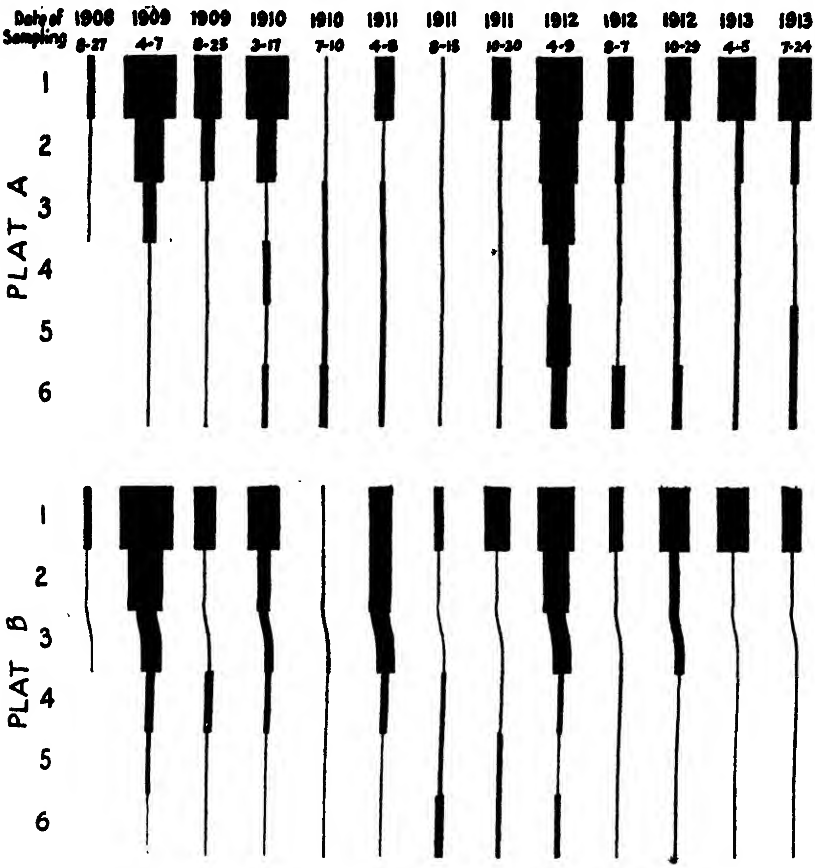


FIG. 7.—Growth-water at seed-time and harvest in spring-ploughed (A) and fall-ploughed (B) plats continuously cropped to grain.

the greatest loss of these components to the washing or blowing away of the surface soil.

Snyder[32] found that the loss of nitrogen from four Minnesota grain-farms in ten years was from four to six times that removed by the crops. This loss he attributes to the rapid breaking-up of the

[31] Bulletin 111, Nebraska Experiment Station, 1909.
[32] Bulletin 94, Minnesota Experiment Station, 1906.

humus under cultivation. Where legumes were grown, crop-rotations practised, live-stock kept, and the farm-manure used, the nitrogen content of the soil was maintained. This practice the dry-farmer of the Great Plains must eventually adopt as far as his conditions will permit, if a permanent agriculture is to be assured in these sections. The American dry-farmer has much to learn from Australian practice in the use of stock, especially sheep, on the dry-farm.

The Water-requirement of Different Dry-Farm Crops.

A word must be said in regard to the importance of considering the water-requirement of crops grown on the dry-farm. Other things being equal, those crops which are most efficient in the use of water are obviously best adapted to dry-land conditions. The great success of millet, sorghum, and maize in American dry-farming is due in part at least to their remarkable efficiency in the use of water. The amount of water required for the production of a pound of dry matter of some strains of alfalfa is four times that required by millet, where the two crops are growing side by side. Different varieties of the same crop often exhibit wide differences in water-requirement. The following figures represent the range in water-requirement due to varietal differences as measured by Briggs and Shantz [33] in the Great Plains.

TABLE III.—*Varietal Range in the Water-requirement of different Crops.*

Crop	Pounds water required to produce one pound of dry matter of the			
	Most efficient variety		Least efficient variety	
	lb.	oz.	lb.	oz.
Millet	261	15	444	9
Proso	268	1	341	10
Sorghum	285	3	467	9
Maize	315	3	413	5
Wheat	473	8	559	4
Barley	502	4	578	13
Oats	559	8	622	9
Clover	789	9	805	8
Alfalfa	651	12	963	9

These wide crop and varietal differences in water-requirement suggest great possibilities in the development of strains for dry-land conditions. In fact, the measurement of the water-requirement affords a novel and promising method of attack in the breeding and selection of dry-land crops.

[33] *Jour. Agricultural Research*, U.S. Department of Agriculture, 3, 58, 1914.

TRANSACTIONS OF THE SECTIONS.

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Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section:
Professor F. T. Trouton, M.A., Sc.D., F.R.S.

Melbourne.

FRIDAY, AUGUST 14.

In the absence of the President, his Address was read by Professor A. W. Porter, F.R.S. :—

We have lost since the last meeting of the Section several distinguished members who have in the past added so much to the usefulness of our discussions. These include Sir Robert Ball, who was one of our oldest attendants, and was President of the Section at the Manchester Meeting in 1887; Professor Poynting, who was President of the Section at Dover in 1899; and Sir David Gill, who was President of the Association at Leicester in 1907.

It seems appropriate at this meeting in the City of Melbourne to mention one who passed away from his scientific labours somewhat previous to the last meeting. I allude to W. Sutherland of this city, whose writings have thrown so much light on Molecular Physics and whose scientific perspicacity was only equalled by his modesty.

This meeting of the British Association will be a memorable one as being indicative, as it were, of the scientific coming of age of Australia. Not that the maturity of Australian science was unknown to those best able to judge; indeed the fact could not but be known abroad, for in England alone there are many workers in science hailing from Australia and New Zealand, who have enhanced science with their investigations and who hold many important scientific posts in that country. In short, one finds it best nowadays to ask of any young investigator if he comes from the Antipodes.

This speaks well for the Universities and their staffs, who have so successfully set the example of scientific investigation to their pupils.

Radio-activity and kindred phenomena seem to have attracted them most of late years, and it would perhaps have been appropriate to have shortly reviewed in this address our knowledge in these subjects, to which the sons of Australasia have so largely contributed.

Twenty-five years ago FitzGerald and others were speculating on the possibility of unlocking and utilising the internal energy of the atom. Then came the epoch-making discovery of Becquerel, to be followed by the brilliant work of Rutherford and others showing us that no key was required to unlock this energy—the door lay open.

We have still facing us the analogous case of a hitherto untapped source of energy arising from our motion through the ether. All attempts, it is true, to realise this have failed, but nevertheless he would be a brave prophet who would

deny the possibility of tapping this energy despite the ingenious theories of relativity which have been put forward to explain matters away. There is no doubt but that up to the present nothing hopeful has been accomplished towards reaching this energy and there are grave difficulties in the way; but 'Relativity' is, as it were, merely trying to remove the lion in the path by laying down the general proposition that the existence of lions is an impossibility. The readiness with which the fundamental hypotheses of 'Relativity' were accepted by many is characteristic of present-day Physics, or perhaps, more correctly speaking, is an exaggerated example of it.

Such an acceptance as this could hardly be thought of as taking place half-a-century ago, when a purely dynamical basis was expected for the full explanation of all phenomena, and when facts were only held to be completely understood if amenable to such treatment; while, if not so, they were put temporarily into a kind of suspense account, waiting the time when the phenomenon would succumb to treatment based on dynamics.

Many things, perhaps not the least among them radio-activity, have conspired to change all this and to produce an attitude of mind prepared to be content with a much less rigid basis than would have been required by the Natural Philosophers of a past generation. These were the sturdy Protestants of Science, to use an analogy, while we of the present day are much more catholic in our scientific beliefs, and in fact it would seem that nowadays to be used to anything is synonymous with understanding it.

Leaving, however, these interesting questions, I will confine my remarks to a rather neglected corner of physics, namely, to the phenomena of Absorption and Adsorption of solutions. The term Adsorption was introduced to distinguish between Absorption which takes place throughout the mass of the absorbing material and those cases in which it takes place only over its surface. If, for instance, glass, powdered so as to provide a large surface, is introduced into a solution of a salt in water, we have in general some of the salt leaving the body of the solution and adhering in one form or other to the surface of the glass. It is to this the term Adsorption has been applied. Physicists have now begun to take up the question seriously, but it was to Biologists, and especially Physiological Chemists, that most of our knowledge of the subject in the past was due, the phenomenon being particularly attractive to them, seeing that so many of the processes they are interested in take place across surfaces.

As far as investigations already made go the laws of Adsorption appear to be very complicated, and no doubt many of the conflicting experimental results which have been obtained are in part due to this, workers under somewhat different conditions obtaining apparently contradictory effects.

On the whole, however, it may be said that the amount adsorbed increases with the strength of solution according to a simple power law, and diminishes with rise of temperature; but there are many exceptions to these simple rules. For instance, in the case of certain sulphates and nitrates the amount adsorbed by the surface of, say, precipitated silica only increases up to a certain critical point as the strength of the solution is increased. Then further increase in the strength of the solution causes the surface to give up some of the salt it has already adsorbed, or the amount adsorbed is actually less now than that adsorbed from weaker solutions. Beyond this stage for still greater concentrations of the solutions the amount adsorbed goes on increasing as before the critical point was reached.

There is some reason for thinking that there are two modes in which the salt is taken up or adsorbed by the solid surface. The first of them results from a simple strengthening of the solution in the surface layers; the second, which takes place with rather stronger concentrations, is a deposition in what is apparently analogous to the solid form. It would seem that the first reaches out from the solid surface to about 10^{-6} cm.—which is the order of the range of attraction of the particles of the solid substance.

The cause of the diminution in the adsorption layer at a certain critical value of the concentration is difficult to understand. Something analogous has been observed by Lord Rayleigh in the thickness of layers of oil floating on the surface of water. As oil is supplied the thickness goes on increasing up to a certain point; beyond this, on further addition of oil, the layer thins itself at some

places and becomes much thicker at others, intermediate thicknesses to these being apparently unstable and unable to exist. As helping towards an explanation of the diminution in the adsorption layer, we may suppose that as the strength of the solution is increased from zero, the adsorption is at first merely an increased density of the solution in the surface layer. For some reason, after this has reached a certain limit, further addition of salt to the solution renders this mode of composition of the surface layers unstable, and there is a breaking up of the arrangement of the layer with a diminution in its amount. We may now suppose the second mode of deposition to begin to show its effect with a recovery in the amount of the surface layers and a further building up of the adsorption deposits.

On account of passing through this point of instability the process is irreversible, so that the application of thermo-dynamics to the phenomenon of adsorption is necessarily greatly restricted in its usefulness.

A possible cause of the instability in the adsorption layer which occurs at the critical point may be looked for in the alternations in the sign of the mutual forces between attracting particles of the kind suggested by Lord Kelvin and others. Within a certain distance apart—the molecular range—the particles of matter mutually attract one another, while at very close distances they obviously must repel, for two particles refuse to occupy the same space. At some intermediate distances the force must pass through zero value. It has for various reasons been thought that, in addition, the force has zero value at a second distance lying between the first zero and the molecular range, with accompanying alternations in the sign of the force. Thus, starting from zero distance apart of the particles, the sign of the force is negative or repulsive; then, as the distance apart is supposed to increase, the force of repulsion diminishes, and after passing through zero value becomes positive or attractive; next, as the distance is increased the force diminishes again, and after passing through a second zero becomes negative for a second time; finally, the force on passing through a third zero becomes positive, and is then in the stage dealt with in capillary and other questions.

As an instance of where these alternations of sign seem to be manifest, may be mentioned the case of certain crystals when split along cleavage planes. The split often runs along further than the position of the splitting instrument or inserted wedge seems to warrant. This would occur if the particles on either side of the cleavage plane were situated at the distance apart where the force between them was in the first attractive condition, for then, on increasing the distance between the particles by means of the wedge, the force changes sign and becomes repulsive, thus helping the splitting to be propagated further out.

Assuming that a repulsive force can supervene between the particles in the adsorption layer, through the particles becoming so crowded in places as to reduce their mutual distances to the stage when repulsion sets in, we might expect that an instability would be set up.

As already stated, a rise in temperature reduces in general the amount adsorbed, but below the critical point the nitrates and sulphates are exceptional, for rise in temperature here increases the amount adsorbed from a given solution. This obviously necessitates that the isothermals cross one another at the critical point in an Adsorption-Concentration diagram. This may perhaps account for some observers finding that adsorption did not change with temperature. We have another exception to the simple laws of adsorption in the case of the alkali chlorides; this exception occurs under certain conditions of temperature and strength of solution. The normal condensation into the surface layer is reversed and the salt is repelled into the general solution instead of being attracted by the surface. In other words, it is the turn of the other constituent of the solution, namely, the water, to be adsorbed.

It is a very well known experiment in adsorption to run a solution such as that of permanganate of potash through a filter of sand, or, better, one of precipitated silica, so as to provide a very large surface. The first of the solution to come through the filter has practically lost all its salt owing to having been adsorbed by the surface of the sand.

I was interested in finding a few months ago that Defoe, the author of 'Robinson Crusoe,' in one of his other books, depicts a party of African travellers

as being saved from thirst in a place where the water was charged with alkali by filtering the water through bags of sand. Whether this is a practical thing or not is doubtful, or even if it has ever been tried; for it is only the first part of the liquid to come through the filter which is purified, and very soon the surface has taken up all the salt it can adsorb, and after that, of course, the solution comes through intact. It is interesting, however, to know that so long ago as Defoe's time the phenomenon of adsorption from salt solutions had been observed. It is not so well known that in the case of some salts under the circumstances mentioned above, the first of the solution to come through the sand filter is stronger instead of weaker. This, as already mentioned, is because water, or at least a weaker solution, forms the adsorption layer.

Most of the alkali chlorides as the temperature is raised show this anomalous adsorption, provided the strength of the solution is below a certain critical value differing for each temperature. For strengths of solution above these values the normal phenomenon takes place.

No investigations seem to have been made on the effect of pressure on adsorption. These data are much to be desired.

The investigation of adsorption and absorption should throw light on Osmosis, as in the first place the phenomenon occurs across a surface necessarily covered with an adsorption layer, and in the second place, as we shall see, the final condition is an equilibrium between the absorption of water by the solution and that by the membrane.

The study of the conditions of absorption of water throughout the mass of the colloidal substance of which osmotic membranes are made is of much interest. Little work has been done on the subject as yet, but what little has been done is very promising

It is convenient to call the material of which a semi-permeable membrane is made the semi-permeable medium. The ideal semi-permeable medium will not absorb any salt from the solution, but only water, but such perfection is probably seldom to be met with. If a semi-permeable medium such as parchment paper be immersed in a solution, say, of sugar, less water is taken up or absorbed than is the case when the immersion is in pure water. The diminution in the amount absorbed is found to increase with the strength of the solution. It is at the same time found that the absorption or release of water by the semi-permeable medium according as the solution is made weaker or stronger is accompanied by a swelling or shrinkage greater than can be accounted for by the water taken up or rejected.

The amount of water absorbed by a semi-permeable medium from a solution is found by experiment to depend upon the hydrostatic pressure. If the pressure be increased the amount of water absorbed by the semi-permeable medium is increased. It is always thus possible by the application of pressure to force the semi-permeable medium to take up from a given solution as much water as it takes up from pure water at atmospheric pressure.

It is not possible for a mass of such a medium to be simultaneously in contact and in equilibrium with both pure water and with a solution all at one and the same pressure, seeing that the part of the medium in contact with the pure water would hold more water than that part in contact with the solution, and consequently diffusion would take place through the mass of the medium.

If, however, the medium be arranged so as to separate the solution and the water, and provided the medium is capable of standing the necessary strain, it is possible to increase the pressure of the solution without increasing the pressure of the water on the other side. Thus the part of the medium which is in contact with the solution is at a higher pressure than that part in contact with the pure solvent; consequently the medium can be in equilibrium with both the solution and the solvent, for if the pressures are rightly adjusted the moisture throughout the medium is everywhere the same.

The ordinary arrangement for showing osmotic pressure is a case such as we are considering, and equilibrium throughout the membrane is only obtained when the necessary difference in pressure exists between the two sides of the membrane.

This condition would eventually be reached no matter how thick the membrane was. It is sometimes helpful to think of the membrane as being very

thick. It precludes any temptation to view molecules as shooting across from one liquid to the other through some kind of peepholes in the membrane.

The advantage of a thin membrane in practice is simply that the necessary moisture is rapidly applied to the active surface, thus enabling the pressure on the side of the solution to rise quickly, but it has no effect on the ultimate equilibrium.

As far as that goes, the semi permeable membrane or saturated medium might be infinitely thick, or, in other words, there need be no receptacle or place for holding the pure solvent outside the membrane at all. In fact, the function of the receptacle containing the pure solvent is only to keep the medium moist, and is no more or no less important than the vessel of water supplied to the gauze of the wet-bulb thermometer. It is merely to keep up the supply of water to the medium.

The real field where the phenomenon of osmosis takes place is the surface of separation between the saturated semi-permeable medium and the solution. Imagine a large mass of colloidal substance saturated with water and having a cavity containing a solution. The pressure will now tend to rise in the cavity until it reaches the osmotic pressure—that is, until there is established an equilibrium of surface transfer of molecules from the solution into the medium and back from the medium into the solution.

No doubt, the phenomenon as thus described occurs often in Nature. It is just possible that the high-pressure liquid cavities which mineralogists find in certain rock crystals have been formed in some such manner in the midst of a mass of semi-permeable medium; the pure solvent in this case being carbon dioxide and the medium colloidal silica, which has since changed into quartz crystal.

In considering equilibrium between a saturated semi-permeable medium and a solution there seems to me to be a point which should be carefully considered before being neglected in any complete theory. That is, the adsorption layer over the surface of the semi-permeable medium. We have seen that solutions are profoundly modified in the surface layers adjoining certain solids, through concentration or otherwise of the salts in the surface layer, so that the actual equilibrium of surface transfer of water molecules is not between the unmodified solution and the semi-permeable medium, but between the altered solution in the absorption layer and the saturated medium. Actual determinations of the adsorption by colloids are much wanted, so as to be able to be quite sure of what this correction amounts to or even if it exists. It may turn out to be zero. If there is adsorption, however, it may possibly help to account for part of the unexpectedly high values of the osmotic pressure observed at high concentrations of the solution, the equilibrium being, as we have seen, between the saturated medium and a solution of greater concentration than the bulk of the liquid, namely, that of the adsorption layer. In addition, when above the critical adsorption point, there may be a deposit in the solid state. This may produce a kind of polarised equilibrium of surface transfer in which the molecules which discharge from the saturated medium remain unaltered in amount, but those which move back from the adsorption layer are reduced owing to this deposit, thus necessitating an increase in pressure for equilibrium. If either or both of these effects really exist, it would seem to require that the pressure should be higher for equilibrium of the molecular surface transfer than if there were no adsorption layer and the unaltered solution were to touch the medium, but at the same time it should be remembered that there is a second surface where equilibrium must also exist—that is, the surface of separation of the adsorption layer and the solution itself. It is just possible that the two together cancel each other's action.

Quantitative determinations of absorption by solid media from solution are hard to carry out, but with a liquid medium are not so difficult. Ether constitutes an excellent semi-permeable medium for use with sugar solution, because it takes up or dissolves only a small quantity of water and no sugar. A series of experiments using these for medium and solution has shown (1) that the absorption of water from a solution diminishes with the strength of the solution; and (2) that the absorption of water for any given strength of solution increases with the pressure. This increase with pressure is somewhat more rapid than if it

were in proportion to the pressure. On the other hand, from pure water ether absorbs in excess of normal almost in proportion to the pressure. Certainly this is so up to 100 atmospheres. This would go to confirm the suggestion already made that the departure from proportionality in the osmotic pressure is attributable to absorption.

By applying pressure ether can be thus made to take up the same quantity of water from any given solution as it takes up from pure water at atmospheric pressure. It is found by experiment that this pressure is the osmotic pressure proper to the solution in question.

Decidedly the most interesting fact connected with the whole question of osmotic pressure, the behaviour of vapour pressures from solution, and the equilibrium of molecular transfer of solutions with colloids, is that discovered by van 't Hoff, that the hydrostatic pressure in question is equal to what would be produced by a gas having the same number of particles as those of the introduced salt. Take the case of a mass of colloid or semi-permeable medium placed in a vessel of water; the colloid when in equilibrium at atmospheric pressure holds what we will call the normal moisture. By increasing the pressure this moisture can be increased to any desired amount. Now, on introducing salt the moisture in the colloid can be reduced at will. The question is, What quantity of salt must be introduced just to bring back the amount of the moisture in the colloid to normal? Here we get a great insight into the internal mechanism of the liquid state. The quantity of salt required turns out to be, approximately at least, that amount which if in the gaseous state would produce the pressure. So that normality can be either directly restored by removing the pressure or indirectly by introducing salt in quantity which just takes up the applied pressure. That this is so naturally suggested that the salt, although compelled to remain within the confines of the liquid, nevertheless produces the same molecular bombardment as it would were it in the gaseous state, though of course the free path must be viewed as enormously restricted compared with that in the gaseous state.

Many have felt a difficulty in accepting this view of a molecular bombardment occurring in the liquid state, but of recent years much light has been thrown on the subject of molecular movements in liquids, especially by Perrin's work, so that much of the basis of this difficulty may be fairly considered as now removed.

Quite analogous to the reduction from the normal of the moisture held by a semi-permeable medium brought about by the addition of salt to the water, is the reduction in the vapour pressure arising from the presence of a salt in the water. The vapour pressure is likewise increased by the application of hydrostatic pressure, which may be effected by means of an inert gas. In both cases the hydrostatic pressure which must be applied to bring back to normality is equal to that which the added salt would exert if it were in the state of vapour, or, in other words, the osmotic pressure.

The two cases are really very similar. In both there is equal molecular transfer backwards and forwards across the bounding surface. In the one a transfer from that solution to the semi-permeable medium and back from it into the solution. In the other a transfer from the solution into the superambient vapour and back from it into the solution.

The processes are very similar, namely, equal molecular transfer to and fro across the respective surfaces of separation.

Thus we may in the case of osmotic equilibrium attribute the phenomenon with Callender to evaporation, but not evaporation in its restricted sense, from a free surface of liquid, but as we have seen from a saturated collodial surface into the solution. This process might perhaps be better referred to as molecular emigration, the term migration being already a familiar one in connection with liquid phenomena.

The following Report and Papers were then read :—

1. *Report of the Committee to Aid in Establishing a Solar Physics Observatory in Australia.*—See Reports, p. 74.

2. *Mount Stromlo Observatory.* By P. Baracchi.

The Government of the Commonwealth, wishing to define a spot within the Federal Territory the meridian of which should be adopted as the Prime Meridian of Australia, to serve as the common longitude datum for all State surveys, decided to mark the spot by erecting upon it a small astronomical observatory which, if the selected site proved to be sufficiently good for the most delicate and important class of astronomical observation and research, was to be expanded and equipped as a modern observatory of the first order, including a department for the study of the sun.

The site was selected in the year 1910; a concrete structure with an eighteen-foot dome was subsequently erected, and a nine-inch refractor by Grubb, equatorially mounted, was installed in September 1911.

With this instrument astronomical observations, visual, photographic and spectroscopic, were carried out during one week of each month in the year 1912 and till April 1913, after which sufficient evidence was collected to show that the site was suitable for a first-class observatory.

Since then this observatory has remained inoperative pending the decision of the Government as to its future.

In this paper the site of the observatory, the instruments, and the work done were briefly described, with the object of placing sufficient information about this matter before the British Association to enable it to recommend to the Commonwealth Government the general lines on which this observatory should be enlarged and equipped, and what should be the programme of its future work.

3. *Proofs of the Sun's Variability.* By C. G. Abbot.

It has been shown by experiments of the Smithsonian Astrophysical Observatory conducted simultaneously at Mount Wilson in California and Bassour in Algeria, in the years 1911 and 1912, that the values of the intensity of the solar radiation outside the atmosphere estimated by spectrobolometric observations at the two stations on the same days are, within the limits of error, identical. The measurements at the two stations agreed within an average deviation of about 1 per cent. It appeared, however, that the values of the solar constant of radiation obtained deviated over a range of nearly 10 per cent. during the continuance of the expeditions. This deviation was observed at both stations, so that if high values were obtained in California high values were obtained simultaneously in Algeria, and *vice versa.* Professor Turner has computed, from the observations, the coefficient of correlation between the results at the two stations. He finds this coefficient to be 52 per cent. plus or minus 7 per cent. if all the observations are used. Rejecting three observations of extreme doubtfulness, the correlation coefficient rises to 60 per cent. This furnishes very strong evidence of the variability of the sun, which appears to be irregular in period and irregular in amplitude, but may range over a course of 5 per cent. or even more within the lapse of a week.

Measurements of the solar constant of radiation have been conducted on Mount Wilson in California by the Smithsonian Astrophysical Observatory for about eight years, though unfortunately the observations have been confined to the months of summer and autumn, when the sky is favourable there for them. It is highly important that such work should be taken up at another station, or preferably at several other stations, where favourable conditions of the sky would be found in the other months of the year.

When the monthly mean values of the solar constant as obtained on Mount Wilson are compared with the sun-spot numbers of Wolfer, it is found that increased sun-spot numbers correspond with increased values of the solar radiation and *vice versa.* Professor Turner has computed the correlation coefficient for these two variables as depending upon fifty months of observations, and finds this coefficient to be 53 per cent. plus or minus 7 per cent. Here also it is seen that a strong proof of the variability of the sun's radiation exists. It appears therefore that the sun, besides varying from day to day in the manner shown by the combined Algerian and Mount Wilson observations, also varies from year to year in connection with the march of the sun-spot cycle.

In September 1913 a tower telescope, forming the image of the sun by the use of mirrors without lenses, and yielding an image of about 9 inches in diameter, was made ready in connection with the station of the Smithsonian Astrophysical Observatory on Mount Wilson. The image of the sun is caused to fall upon the slit of a spectrobolometer, which slit for this purpose is only about three eighths of an inch in height. By stopping the clock of the telescope the solar image drifts centrally across the slit of the spectrobolometer, owing to the diurnal rotation of the earth. There is thus produced, by automatic registering of the indications of the bolometer, a curve of distribution of intensity along the diameter of the sun's disk. This curve takes the form of a letter U. The length of the straight sides of the U may be taken as representing the intensity of the solar radiation at the edge of the sun's disk, and the height of the U to the centre of the curve may be taken as representing the intensity of the radiation at the centre of the disk. Thus a contrast of the intensity of radiation along the diameter of the sun is made manifest. Observations were made on nearly fifty days of the year 1913 with this apparatus, and on each day the distribution of intensity at seven different wave-lengths of the spectrum between 3,700 ångströms and 10,000 ångströms was determined by making two curves at each wave-length. On the same days the solar constant of radiation was determined at Mount Wilson.

Work with a similar object, but done in different ways, has been carried on by Vogel, Pickering, Langley, Very, Schwarzschild and Villager, and Abbot and Fowle. It is found by comparison of the distribution curves obtained at Mount Wilson in 1913 with others obtained by Abbot and Fowle in 1907, that a change of form of the distribution curve has occurred between these epochs. The contrast of brightness between the centre and edge of the sun in the year 1907 was greater than the contrast found in the year 1913. This is verified at all wave-lengths, but the change of contrast is greater for short wave lengths than for longer ones.

It further appears, by comparison of results of one day with another in the year 1913, that a change of contrast of brightness is going on all the time, similar in irregularity of period and amplitude with the variation of the sun's total radiation which was found by comparison of Mount Wilson and Bassour observations. When the daily values of the solar constant of radiation obtained in 1913 are compared with the distribution of brightness along the sun's diameter, it is seen that a close correspondence of variation occurs between the two. This daily variation is of such a nature that when the solar constant values increase the constant of brightness between the centre and edge of the sun diminishes. The result is contrary to that which was indicated by a few observations of Abbot and Fowle in the year 1908. It is believed on further examination that the results of Abbot and Fowle in 1908 were made erroneous by certain defects in the measurements of the solar constant of radiation on two or three days. The new results come from nearly fifty days of observation, and are quite definite in showing the connection between the variation of the radiation of the sun and the variation of brightness along the sun's diameter.

It appears, however, that the correlation between solar constant values and contrast values between the years 1907 and 1913 is contrary in its sign to the correlation between these variables exhibited by the daily march of values for the year 1913. This may point to a greater complexity of the solar problem than was at first indicated by the results of Abbot and Fowle. It may be that the march of the sun-spot period attends an influence in one direction, while the march of short-period fluctuations of the solar radiation from day to day attends a change of contrast in the other direction.

4. *Discussion on the Present State of the Problem of Australian Longitudes. Opened by* P. Baracchi.

In Mr. Baracchi's paper were discussed the longitude values assigned to the two Australian meridians of Port Darwin and Southport (Queensland); these being, respectively, the terminals of the two chains of telegraphically determined longitudes carried eastward from Greenwich *via* India, Singapore, and

Port Darwin, in one case, and westward through Canada and the Pacific Ocean to Southport (Queensland) in the other case.

It was also shown that the connection between these two meridians obtained by means of the measured longitudinal arcs Port Darwin-Melbourne, Melbourne-Sydney, and Sydney-Southport (Queensland) completes a whole longitude circuit round the Earth, with a closing error of less than a hundred feet.

The reality of such a small error was questioned, chiefly on the ground that larger discrepancies were found in the independent results of certain links which have been measured more than once.

It was pointed out that in order to render the whole of this important longitude circuit homogeneous and reliable a re-measurement should be made of the arcs Madras-Singapore, Singapore-Port Darwin, and Port Darwin-Southport (Queensland), adopting the highest refinements of modern practice and present instrumental means.

The object of the paper was to enlist the sympathy of the British Association in this matter, and to obtain its advice as to the most practical and efficient plan of carrying out the work.

TUESDAY, AUGUST 18.

Joint Meeting with Section B (Chemistry).

Discussion on the Structure of Atoms and Molecules.

Sir ERNEST RUTHERFORD (abstract of remarks): In recent times there has been an accumulation of convincing evidence of the independent existence of the chemical atom. The atomic theory is no longer merely an hypothesis introduced to explain the laws of chemical combination; we are able to detect and count the individual atoms. We can determine the actual mass of an atom in various ways, and know its value with considerable accuracy. The idea that the atom is an electrical structure received a great impetus by the detection of the electron by J. J. Thomson; and, moreover, the Zeeman effect showed that all atoms must contain electrons. The atomic character of negative electricity is well established: we always find the negative electron, however produced, carrying a definite charge. We have, unfortunately, not the same certainty with regard to the behaviour of positive electricity, for it cannot be obtained except associated with a mass comparable with that of a hydrogen atom. In J. J. Thomson's model of the atom the positive electricity was supposed (for mathematical reasons) to be distributed throughout a large sphere with the negative corpuscles moving inside it. This hypothesis has played a useful part in indicating possible lines of advance; but it does not fit in with more recent discoveries, which point to a concentrated positive nucleus.

We have now two powerful methods that aid us in determining the inner structure of the atom—the scattering of high-speed particles in transit through matter, and the vibrations of the interior parts of the atom. In C. T. R. Wilson's photographs of the tracks of the α particles through a gas we notice many sudden bends in the paths. In order to account for these deflections I have found it necessary to believe that there is a concentrated nucleus in the atom (having a certain number of units of charge), in which the main part of the mass resides; outside this there are a corresponding number of electrons. The whole dimensions of the nucleus are very small indeed compared with the distance of the outer electrons. From the scattering experiments it appears that the law of force right up to the nucleus is the inverse square law; no other formula would give accordance with the observations. The radius of the nucleus is of the order 10^{-12} cm. in the case of gold, and for a lighter element it is smaller still. The approach of the α particle to the nucleus of the hydrogen atom when the latter is set into very swift motion is exceedingly close—a distance even less than the diameter of an electron. From this it is probable that the hydrogen nucleus is simply the positive electron with a large electrical mass due to the great concentration of the positive charge. Another

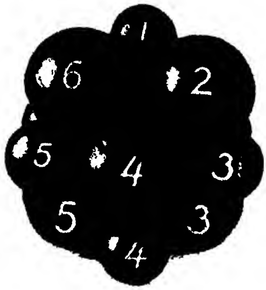
fact that appears from the scattering experiments is that the number of electrons (outside the nucleus) is about half the atomic weight. There is now fairly good evidence that, if the elements are numbered in order of atomic weight, the numbers will actually express the charge on the nucleus. The rate of vibration of the inner parts of the nucleus can now be measured by means of the characteristic X-rays emitted. Each substance has several strong lines in its X-ray spectrum, and as we pass from element to element in order of atomic weight the frequencies of these change by regular jumps. H. G. J. Moseley has investigated all the known elements in this way, and he is even able to show at what points elements are missing, because at such points the X-ray frequencies make a double jump. In this way he has found that between aluminium and gold only three elements are now missing. It is deduced from these considerations that there is something more fundamental in the atom than its atomic weight, viz., the charge on the nucleus, and that this is the main factor which controls the frequency of the interior vibrations, the mass having only a slight influence.

There are certain elements with identical chemical properties, but different atomic weights. Thus Radium-B (atomic weight 214) and lead (207) are chemically inseparable and have the same γ-ray spectrum. It is quite clear that some new conception is required to explain how the atoms, having the structure we have supposed, can hold together. N. Böhr has faced the difficulty by bringing in the idea of the quantum in a novel way. At all events, there is something going on in the atom which is inexplicable by the older mechanics.

Professor Armstrong: Although chemists must admire as well as welcome the bold attempt physicists are making to unravel the structure of the elementary atom, they cannot yet with advantage discuss the conclusions arrived at by their colleagues; the arguments used are so novel and daring, the contentions so original, that at present they are not in a position to appreciate, still less to criticise them effectively; in fact, the chemist's office at the moment must be mainly to point out the conditions that a theory must satisfy to meet his requirements. He has long been prepared to believe that the materials spoken of as elements may prove eventually to be compounds; indeed, the relationships between them are so similar to those manifest between carbon compounds, and of such a character, that it is almost necessary to believe in their composite nature; but the views that are now advocated by physicists are entirely different from any conceptions that chemists have ever entertained and cannot easily be assimilated by them. Physicists, unfortunately, in the past have held aloof from chemists; they have paid too little attention to their methods and to their results; the movement now in progress is therefore to be welcomed, as it must have the effect of leading the two parties in future to work together to a common end. Hence the value of the present discussion.

It is doubtful if it be permissible at present to conclude that elements of different atomic weight may and do exist which are indistinguishable chemically: the observations on which reliance is placed have been made with quantities of material far too small to permit of such an inference; in the case of the rare earth elements, although very large quantities of material have been at the disposal of chemists, they have only slowly discovered differences by which they are enabled to distinguish and separate them. Though the special methods made use of by physicists are very powerful, they suffice only in certain cases and have little chemical significance; when physicists resort to chemical methods the work becomes subject to ordinary criteria.

The resemblance of the X-ray spectra of so many elements is undoubtedly most significant, but to conclude, on such evidence, that all but very few of the elements are discovered is scarcely justifiable; it may well be that most of those that are known belong to a certain 'preferred' type and that a particular series is nearly complete, the similarity of the spectra being perhaps due to the presence of a radicle common to the series, much as in the case of a series of related benzenoid compounds. In the case of carbon compounds, of the large number of series possible, it is well known that certain types are formed preferentially, being more stable or more readily produced than others. If the so-called elements are compound substances, it may well be that the occurrence



Barlow-Pope Model of Benzene

The same, showing arrangement of space affinities

Illustrating Discussion on the Structure of Atoms and Molecules.

(From *Proc. Roy. Soc.*, 1914, Series A, Vol. 90, pp. 113, 146 ; by permission of the Royal Society.)

[*To face page* 295.

and prevalence of a certain type is determined in a somewhat similar way—that some one type has been preferred.

Any theory of atomic structure to be satisfactory to chemists must take fully into account the peculiar valency relationships that are manifest among the elements, as the system of 'structural' formulæ now in vogue is based solely upon these. The system is admittedly one of extraordinary perfection and remarkably simple. In the case of organic compounds, the rules laid down have been found to be applicable and to suffice in so many thousands upon thousands of cases that it is impossible to doubt their general correctness; at most it will be necessary eventually to translate them directly into some new language. It should be pointed out, however, that so-called structural formulæ are to be regarded as condensed symbolic expressions indicative of the general behaviour of the compounds represented in terms of certain well-understood conventions, rather than as actual representations of structure. For example, it is customary to represent benzene by a regular hexagon, a symbol which is a complete expression of the chemical behaviour of the hydrocarbon. But the six carbon atoms are not to be thought of as arranged in a plane and in a ring in the manner depicted by the symbol; such an arrangement is impossible if the affinities of the carbon atom act tetrahedrally. The structure of benzene is rather to be represented by a model in which six carbon atoms (represented by six large spheres) are arranged three and three, in two superposed layers, union taking place between an atom in one plane with a contiguous atom in the plane above, which in turn is united to that in the plane below—so that the atoms are connected in zigzag fashion; and the six hydrogen atoms are to be thought of as severally united to the six carbon atoms in such manner that the hydrogen atom is always in a plane different from that which contains the carbon atom with which it is connected. If the 'atoms' in such a model are squeezed down into one plane, the projection is practically identical with the ordinary 'centric' symbol of benzene. *The arrangement referred to is shown in the accompanying figures (see Plate).*

The fundamental assumption made by chemists, upon which their system of structural formulæ is based, is that the hydrogen atom has unit valency—that it is incapable of acting as a linking element. The whole of the evidence available appears to be in favour of this view. The contention advanced recently by Sir J. J. Thomson that hydrogen may occur as a triatomic molecule, H_3, is therefore unacceptable; until the existence of such a molecule has been proved up to the hilt it will be impossible for chemists to admit its existence. The artifice by which Sir Joseph Thomson has sought to reconcile his interpretations with those of chemists practically involves the representation of hydrogen as a dyad; if this conclusion were accepted it would be necessary to double the valency of all other elements, a step which cannot be justified on chemical evidence. It is in cases such as these that a better understanding between chemists and physicists is required.

The variation of valency is probably the most perplexing phenomenon in chemistry. It is doubtful if any element have a higher 'true' or fundamental valency than carbon; the view sometimes put forward that certain elements may function even as octads is based on evidence which in no way justifies such an assumption. Not only will it be necessary to account for the variation in valency from element to element but also for the fluctuations observed especially in the case of the non-metallic elements. The variation seems to be determined by some reciprocal relationship between the interacting elements, valency apparently being a dependent variable rather than an absolute property; thus, to quote examples, whilst the hydrocarbon, CH_2, is non-existent and cannot exist *per se*, the corresponding oxide, carbonic oxide, CO, is not only stable but relatively inert, combining with other substances only under special conditions; and the corresponding sulphur compound is so active that it cannot exist independently, but at once undergoes polymerisation with explosive violence. Yet sulphuretted hydrogen occurs as a gas of simple molecular composition, whilst water, being a liquid of relatively high boiling-point, is presumably of considerable molecular complexity, so that it must be supposed that the fundamental molecule OH_2 is a highly active material. No theory of

atomic structure will be acceptable unless it can account for variations such as these.

Besides considering variations in atomic properties such as have been referred to, it will be necessary also, in devising a theory of atomic structure, to take into account the fact that valency is a 'directed function.' The tetrahedron apparently is a complete embodiment of the properties of the carbon atom, in so far as these are due to directed forces, if the affinities of the atom be thought of as proceeding from the centre of mass to the four apices. Or if, instead of representing carbon by a sphere four times the volume of the unit sphere representing the hydrogen atom, four unit spheres be piled in tetrahedral form, the four hollows into which other similar spheres will fit are in positions representing the directions in which affinity acts. The great body of facts arrived at by studying optically active 'asymmetric' carbon compounds are all compatible with such modes of representing carbon; moreover, the hypothesis is the only one devised that sets the necessary limit to the number of isomerides possible. What is true of carbon is true apparently of other elements. But it is very noteworthy that the affinity of carbon atoms for carbon atoms, as well as for those of many other elements, is extraordinarily strong in comparison with that of other elements for each other; carbon has properties which are altogether peculiar.

Fresh significance has been given to the problems of valency of late years owing to the introduction, by Barlow and Pope, of the conception that it is to be regarded as a function of the volume occupied by the atom. Assuming that the atoms are closely packed, they have succeeded to an extent which is altogether remarkable, by means of this hypothesis, in correlating crystalline form with molecular structure. Regarding the sphere within which the influence of the hydrogen atom is exercised as unity, that of the dyad elements is twice, that of the triad three times, that of a tetrad element such as carbon four times, as great as that of the hydrogen atom. The halogens appear to occupy the same relative volume as hydrogen. A large body of evidence to this effect is to be found in a recent communication to the Royal Society ('Proc. R. Soc.' A, vol. 90, p. 111, 1914). Apparently, when an element such as an atom of halogen is introduced in place of hydrogen, the alteration in volume which attends the change is not simply due to the displacement effected by the new atom: the alteration in composition involves *alterations in the spheres of influence of all the atoms in the molecule*, so that their relative volumes remain the same though their actual volumes may vary.

It is to be expected that many of the problems of molecular structure which in the past could not be considered, especially in the case of inorganic compounds, will now be amenable to treatment from the crystallographic side. The view originally put forward by Lavoisier and elaborated by Berzelius, that acids such as sulphuric acid are compounds of an acid oxide with 'water,' may be referred to as a case in point (see 'Proc. R. Soc.' A, vol. 90, p. 73, 1914).

In view of the production of helium in so many cases of 'atomic' disruption, it must not be forgotten that the problems of 'elementary' atomic structure still require study on the chemical side. It is not to be supposed that they are no longer amenable to chemical treatment and that they are ripe for purely physical treatment.

Professor Hicks: Professor Rutherford has approached the question chiefly from the side of radioactive phenomena, whilst Professor Armstrong has dealt with certain stereographic properties of the molecule which physicists must take account of in forming any theory of the structure of the atom itself. I propose to draw attention to certain aspects of the problem when approached from the spectroscopic side, *i.e.*, from consideration of the atom as a configuration capable of emitting definite sets of free vibrations. Before doing so, however, I should like to offer some criticism with reference to a point raised by Professor Rutherford, viz., the actual value of the effective nuclear charge in any case. Moseley's law indicates that they are consecutive multiples for the consecutive elements in the periodic table, and they are known if that for one, say He, is known. What evidence we have seems to me rather to weigh in favour of He having an atomic number 4 in place of 2 which is assumed by Rutherford, Böhr, and Moseley himself. That it is at least 2 is clear from

the double charge on the α particle, but it does not follow when two of the movable electrons are freed that nine are left bound with the nucleus. The supposition that the atomic number for H is 1 and for He is 2, means that there are no intermediate elements between them. But there are several considerations which point to the existence of 2. (1) Nicholson has given very weighty reasons for supposing that the lines observed in the corona and in nebulæ are due to two elements whose atomic weights lie between those of H and He, which he has called respectively Coronium and Nebulium. Their nuclear charges, however, are 4 and 5, which would make He 6. (2) Rydberg has proposed a theory of the constitution of the periodic table which has been remarkably justified in one respect by Moseley's measurements, in so far that it requires 32 elements between Kr and Ra.Em in place of 36 as hitherto supposed. The same reason which requires these 32 elements also requires 2 between H and He. (3) In the July number of the 'Philosophical Magazine' Rydberg has discussed Moseley's measurements of the frequencies of the Barkla K and L series, and finds that if N—the atomic number—be based on 4 for He, the frequencies of the lines can be represented by the following scheme: —

K(α) and K(β)	by	$P(N-3)^2$	$P(N-3{\cdot}5)^2$
L(α) and L(β)	„	$P(N-3\times 3)^2$	$P(N-3\times 3{\cdot}5)^2$
L(γ) and L(δ)	„	$P(N-4\times 3)^2$	$P(N-4\times 3{\cdot}5)^2$

but that such an arrangement is impossible if N be based on any other number than 4 for He. More exact numbers, however, are needed before these relations can be regarded as established.

We already know certain definite facts as to the constitution of an atom. They are: —

(1) All atoms contain electrons as a part of their constitution. Of these they can apparently lose a certain number without altering their chemical identity, whilst in the case of radioactive elements the loss of other sets changes them into different elements. We shall doubtless be justified in the assumption that the same law extends to all elements.

(2) There exist also positively charged nuclei associated with the atomic mass, containing multiples of the fundamental electric charge, and the evidence tends to show that the chemical nature of the element is determined by this multiple.

(3) In the case of a certain number of substances there are found associated magnetic doublets whose moments are multiples of a definite quantity, called by Weiss the magneton. It appears legitimate to suppose that the same phenomenon may exist in other elements, though whether the magneton has an independent existence or is a consequence of electronic motion is an open question. If the latter, an explanation of the multiple quality will have to be sought for.

Any theory of atomic structure must, then, be a theory of the way in which the atom is built up of these fundamental quantities. So far there are two types: (1) Thomson's theory of an extended positive nucleus within which the electrons revolve in Saturnian systems; (2) Rutherford's theory of an extremely small nucleus with electrons in planetary or Saturnian orbits. Neither of them, however, has shown the slightest aptitude in explaining the series laws of spectra. The actual structure must be a much more complicated one than is assumed in either. Unfortunately the complete mathematical treatment of the simplest case is one of extreme difficulty. We may, however, I believe, make one very important first step, viz., as to the direction in which to look for the source of the energy emitted in spectral radiations. This energy may arise either from small vibrations about a stable state or from change from one stable state to another. In both cases the stable states must be such as to lose no energy; and must therefore be in static equilibrium, or their relative motions must be such as to produce no change in an external field relative to itself—such as, for instance, a charged sphere moving with uniform velocity. In the first case the energy would be made up of extremely small amounts from all the atoms, and an increase in intensity would be due to increased ampli-

tudes. In the second case it is made up by relatively large amounts from a proportion only of the systems, and an increase would be due to a larger proportion of atoms changing from one system to another. In the first case, although the constancy of period follows as a matter of course, it is difficult to see how the conditions of Planck's quanta can be met, and that the ideas lying at the base of his theory are well founded there can be little doubt. In the second case the energy for each line is transferred in the same amount, and the constancy of the frequency follows at once from Planck's theory. These general considerations seem to point to the conclusion that the cause of spectral emission is change from one configuration to another of less internal energy. But there is experimental evidence pointing in the same direction. Stark has shown that the series lines in a spectrum are due to molecules which have lost one or more electrons. For instance, doublet series are due to molecules which have lost one electron, triplets two, &c., and we should therefore expect the energy emitted to be given out by their recombination to the neutral state. Since in general the larger proportion of spectral lines—both arc and spark—are either series or seem to be closely related to series lines, it would appear that change of state is one of the chief causes of radiation.

A further consideration pointing in the same direction is afforded by the fact that the formulæ to which series lines conform give the frequency itself, and not the square of the frequency, which latter is always the case when the forces of displacement are proportional to the displacements themselves. As Rayleigh has pointed out, the former case requires forces proportional to the velocities, and hence suggests motion in magnetic fields. Now we know these fields exist, and as a fact the only theory which reproduces Rydberg's formulæ is that of Ritz, depending only on magnetic fields. Unfortunately electrostatic fields exist and must be taken account of. If we could conceive of shells of constant magnetic force produced by electric charges moving in such a way that the electric forces between the moving charges themselves are annulled, we should have made a first step towards forming a basis of a satisfactory theory. That such motions are possible is rendered probable from consideration of Maxwell's classical case of two uniformly charged parallel plates moving parallel to one another with the velocity of light. The great desideratum in the present state of the question is, not attempts at forming a complete theory, but mathematical discussions of as many simple cases as possible, in order to obtain a clearer comprehension of what such systems may be expected to explain. From this point of view the recent most suggestive paper of Conway on 'An Electromagnetic Hypothesis as to the Origin of Series Spectra'[1] is of the greatest value. We want more of a similar nature.

Whilst, however, in all probability the greater portion of a spectrum is due to changes of configuration, it does not necessarily follow that lines related to the series are the only ones emitted. In fact, the high-frequency vibrations discovered by Barkla and measured quite recently by Moseley are clearly a case in point. Nicholson has determined recently the frequencies of small oscillation of electrons revolving round positively charged nuclei on the basis of the Rutherford theory. More especially he finds that the sets of lines observed in the corona and in nebulæ fit in very exactly for elements in which the nuclear charges are respectively 4 and 5, and the lines are due to neutral atoms and also to atoms which have lost or gained one or two or more electrons. The agreements are so close and so numerous as to leave little doubt of the general correctness of the theory. But the lines are certainly not connected in any way with the series type of line. Their appearance is probably due to the vast number of atoms in the corona and nebulæ in the line of sight all emitting vibrations, whilst the absence of the series type may be due to the rarefaction of the gas causing comparatively few changes from one configuration to another. Nicholson's theory stands alone as a first satisfactory theory of one type of spectra. Unfortunately this type contains so few examples that if they exist in other elements they have not been noticed. It affords considerable evidence that Rutherford's theory approximates to the actual case when the nuclear charge is a small multiple of the fundamental charge. Several attempts have

[1] *Phil. Mag.* xxvi. p. 1010, December 1913.

been made to apply Planck's theory of radiation to the explanation of the laws of spectra. The most ingenious and suggestive is that of Böhr. It is based on the Rutherford atom, but throws no further light on the structure of the atom itself, as the mechanism of radiation is totally unexplained, and it is this which we are in search of. The most remarkable result is the derivation of the value of Rydberg's constant from known electric constants, and Planck's constant. This result has certainly caught the scientific imagination, and one feels convinced, especially on a first reading of his paper, that there is some truth at the bottom of his theory. But Lindemann has pointed out, by consideration of dimensions, that a large number of theories would give values in which the various constants enter in the same way. In Böhr's theory the exactness of the numerical relation depends on an apparently arbitrary assumption as to the frequency of the energy emitted when an electron is combined. It is true that later he attempts to justify this by making his formula conform to certain observed properties of series. But with the introduction of this his value of Rydberg's constant ceases to be a direct deduction from his theory. Moreover, in doing so he assumes the frequency of an electron to be proportional to its angular velocity, which can only be the case for *one* electron—*i.e.*, for an atom built on a planetary system, and not on a Saturnian, as is his. Nicholson has recently criticised the theory on other grounds, and as he is to take part in the discussion I will leave this point to him. From the spectral point of view the weightiest objection would seem to be that it is capable only of giving a formula of the Balmer type—which holds for hydrogen alone. In the best-known series types, the P, S, and D depend on formulæ of the type $A - \frac{N}{(m-\mu)^2}$. The μ depend on atomic constants, and are always considerable for elements of large atomic weight. As the atomic weight diminishes we get the following general changes:—In P, μ decreases to 1; in D it increases to 1; in S it approaches the value ·5. In other words, for P and D the formulæ approach a Balmer type. For H it is indistinguishable from Balmer's. For He, though approaching Balmer's, it is decisively not 1. As a fact, Böhr's theory does not represent any of the six known series of He, but he postulates that certain lines hitherto allotted to H belong really to He. Moreover, he supposes He to have 2 electrons, whereas, as I have attempted to show above, the number is more probably 4. Fowler has recently presented a paper to the Royal Society in which he supports Böhr's allocation on observational grounds, but as it is not yet (August) published it is not possible to weigh the evidence. In concluding, I should like to say that although I have criticised certain parts of Bohr's theory adversely, no one can admire more its ingenuity and great suggestiveness.

Mr. H. G. J. MOSELEY explained the results of his classification of elements by their X-ray spectra. The frequency of the principal line in the X-ray spectrum is represented very closely by the formula

$$\gamma^{\frac{1}{2}} = K\ (N - B)$$

where K and B are constants, and N an integer increasing by a unit as we pass from element to element up the periodic table. If we take this atomic number N as ordinate, and the square root of the principal frequency as abscissa, the different elements will therefore give points lying approximately on a straight line. The secondary frequencies will at the same time give points on other straight lines. The order of the elements determined by N is nearly that of increasing atomic weight; there are one or two exceptions, and in such cases the order given by N, and not the atomic weight, is evidently the correct order corresponding to chemical properties. For example, the atomic weight gives the order Cl, K, A, whereas the X-ray frequency gives the order Cl, A, K. The latter is the order required by the periodic table. There are between aluminium and gold four missing elements, indicated by the double jump of N required to make the formula fit. These correspond generally to gaps indicated also by the periodic law.

Professor NICHOLSON: I prefer not to introduce new difficulties, which would only make the discussion too long, and will therefore confine my remarks to

those points on which my opinion has been invited by Professor Hicks. Firstly, with regard to Böhr's theory, such criticisms as I have made are in the main mathematical, and therefore unsuitable for a joint discussion between physicists and chemists. But I can give a statement of the present position of the theory as it appears to me. When Böhr's theory is applied to a single nucleus of strength e or $2e$, with a *single* rotating electron, it is remarkably successful in its deduction of the hydrogen series spectrum and of the Pickering series which it ascribes to helium. Its most striking success is, I think, not the very accurate deduction of the universal constant of spectra, but its application by Professor Fowler in his Bakerian lecture to a determination of the mass of an electron, on the supposition that the Pickering series comes from helium. The accuracy of this value cannot be ignored. But analysis shows that it is quite impossible to go further, and to derive the usual helium spectrum. I mean that in order to do so we must abandon at least one of Böhr's premises which is vital to the deduction of the hydrogen formula. This fact is capable of rigorous demonstration, as is also the fact that, under the inverse square law, which Sir Ernest Rutherford has shown experimentally to be valid, Rydberg's constant is not a feature of more complex atoms on this theory.

There is also an experimental difficulty. Whatever its origin, the Pickering series should be accompanied by an ultra-violet one in the Schumann region. This series has been found by Professor Lyman in the hydrogen spectrum, whereas helium appears to have no Schumann spectrum. Professor Lyman is repeating these experiments, in view of their importance, but the balance of experimental evidence is against Bohr's theory at present.

I am inclined to agree with Mr. Moseley that my nebular and coronal elements may not be chemical elements in the ordinary sense. This opinion, that they are sub-elements, or bases of ordinary elements, will be found in my papers. Bourget, Buisson, and Fabry's experiments, described in the 'Comptes Rendus,' show that these substances have the atomic weights which I calculated theoretically from their spectra, so that their existence appears to be real. Moreover, as in my papers, ordinary elements with series spectra can apparently only be formed from them by an alteration in the nucleus which does not affect its total charge. Evidence is accumulating to show that the nuclear structure may play an important part in series spectra, and therefore I am not inclined to agree with Professor Rutherford that the nucleus of a hydrogen atom is necessarily the positive electron. It seems to be more complicated. But with everything else in his admirable opening address I must express a general agreement. I must finally agree with Mr. Moseley that any ultimate atomic theory must involve Planck's h. In my own papers this was regarded as an angular momentum, as subsequently also by Bohr. The necessity for it is easily seen. For we only have one dynamical relation between the radius of the atom and the angular velocity of its electrons. Without the introduction of some new universal constant such as h no atom has anything in its nature which compels a definite size, and definite unchanging properties.

Professor H. Bassett said that, as the number of elements which came before neon seemed of considerable importance in connection with the theoretical treatment of the constitution of the atom, it might be worth while considering whether the periodic law gave any hints on the matter. It was well known that Lothar Meyer's atomic volume curve clearly demonstrated that, although the properties of the elements were periodic functions of their atomic weights, the periodicity was not of such a simple character as at first supposed by Newlands. Leaving out hydrogen for the moment, it was found that there were two short periods of eight elements each, beginning with neon and argon, and ending with fluorine and chlorine respectively, followed by two long periods of 18 elements—that was to say, of $(2\times8)+2$ elements. These two long periods were followed by one very much longer period and a portion of a second. Unfortunately this very long period was so far incompletely known, and it was not certain how many elements it contained; but this much could be said, namely, that it contained approximately twice as many elements as one of the long periods, and possibly 38 elements, which would be $(2\times18)+2$

elements. Now, going back to the region in which hydrogen was situated, one was tempted to suggest that this gas was the only known representative of an extra short period of three elements. Doubling this number and adding two one obtained eight—the number of elements in each of the known short periods. Doubling eight and adding two one obtained eighteen—the number of elements in each of the long periods, and so on. Although such treatment of the matter might appear like playing with figures, it seemed to the speaker of some interest.

Professor KERR GRANT summarised the difficulty as to the stability of a system consisting of one nucleus and one electron. It was difficult, too, to account for the non-magnetic character of the hydrogen atom with this structure. Magnetism, however, depended probably more on molecular than on atomic structure.

Sir E. RUTHERFORD (replying) said that the chemical inseparability of certain isotopes was, indeed, derived from experiments with small quantities, but the methods used were very delicate. The separation of Radium D from lead was a most important problem; there seems evidence that different leads exist, having different atomic weights. The difficulty of stability is common to all theories of the atom; but what it points to is that there is something wrong with the theory of electromagnetic radiation--not of the atom.

The following Paper was then read :—

On Salts coloured by Cathode Rays. By Professor E. GOLDSTEIN.
See Reports, p. 250.

The following Papers were read in Section A :—

1. *Note on the Magneton as a Scattering Agent of α and β Particles. By* Professor W. M. HICKS, *F.R.S.*

Weiss has proved the existence of elementary magnetic magnets—or their equivalent—as a constituent of the atoms of matter. These magnetons should act as very effective scatterers of α and β rays, but the mathematical difficulties of a complete discussion of the scattering by a single electron are probably extremely great. The particular case where the electrons move in an equatorial plane of the magneton admits, however, of a complete mathematical solution, and may be useful as throwing some light on the nature of the scattering to be expected. It is essentially a question of the orbits of charged particles coming from an infinite distance, and in the paper the nature and distribution of these are explained. Incidentally also a theory of combined electrons appears.

2. *Demonstration of a Mechanical Analogue of Wireless Telegraphic Circuits. By* Professor T. R. LYLE, *F.R.S.*

3. *On the Thermal Conductivity of Air. By* Professor T. H. LABY *and* E. O. HERENS.

4. *The General Magnetic Survey of Australia. By* E. KIDSON.

WEDNESDAY, AUGUST 19.

Discussion on Antarctic Meteorology. Opened by G. C. SIMPSON, *D.Sc.*

1. A brief résumé was given of the general circulation in the atmosphere over the Southern Hemisphere as taught by:

(*a*) the text-books.

(*b*) Dr. Lockyer in his paper 'Southern Hemisphere Surface Air Circulation.'

(*c*) Professor Meinardus in his discussion of the result of the 'Gauss' Antarctic Expedition.

Dr. Lockyer suggests an intense anticyclone over the Antarctic Continent, from which cold air feeds into a series of large cyclones circulating the southern ocean and having their centres near to 60° S. The cyclones are supposed to be so large that while their southern extremities sweep over the edge of the Antarctic Continent their northern extremities reach to latitude 40° S., and so dominate the weather of Tasmania and New Zealand, and to some extent that of South Australia.

Professor Meinardus's scheme also includes a series of cyclones travelling from west to east over the southern ocean; but he gives strong reasons against the presence of an anticyclone over the southern continent. His chief objection to such an anticyclone is that anticyclonic conditions are accompanied by an excess of evaporation over precipitation; hence it would be impossible to account for the excess of precipitation which gives rise to the large glaciers and snowfields which discharge the known large quantities of ice.

2. The simultaneous observations made at Cape Evans, Cape Adare, and Framheim were then considered to investigate the processes which are at work in the Ross Sea area. Diagrams showing the mean temperature distribution both horizontally and vertically were examined, and the curves of barometric pressure and wind at the different stations compared. The chief conclusions of the investigation are as follows: The high south-easterly winds—commonly called blizzards—are not caused by cyclones passing into the Ross Sea, but are the result of the large differences of temperature which exist in the lower atmosphere over the Barrier and the Ross Sea. The cloud observations show that air feeds into the Antarctic at high levels, and passes north again in the blizzards. Meinardus's objection that in such a circulation of air precipitation would not exceed the evaporation was shown not to hold, because of the great cooling of the air due to radiation. The air while sinking loses so much heat by radiation that, when forcibly made to rise in the blizzards, saturation is reached at a much lower level than that at which the air entered. Thus anticyclonic conditions are consistent with an excess of precipitation.

3. The existence of a belt of cyclones between the Antarctic Continent and Australia was then considered. Curves on which barometer and wind observations made at the 'Gauss' winter quarters are plotted were shown. From them it was seen that during the passage of deep waves of pressure there is practically no variation of the wind direction at that station. In most cases the wind blows a gale from the east both while the barometer falls rapidly and while it makes an equally-rapid recovery. At present it appears quite impossible to reconcile the wind and barometer observations with any system of circulation of wind about a centre of low pressure moving from the west to the east. Further the simultaneous barometer observations at Melbourne, the Bluff (New Zealand), and Cape Adare were examined without finding any certain indication of the same cyclone affecting the northern and southern stations.

4. The monthly departures from normal of pressure at Cape Evans were compared with corresponding values for stations in Australasia, and an important negative correlation was found.

5. In conclusion the importance of a permanent meteorological station on the Antarctic Continent was urged.

The following Report and Papers were then read:—

Report of the Seismological Committee.—See Reports, p. 41.

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2. *On the Change of Thermal Conductivity during the Liquefaction of a Metal. By* Professor A. W. Porter, *F.R.S., and* F. Simeon.

3. *Experiments on the Active Deposit of Radium. By* E. Wellisch.

SYDNEY.

FRIDAY, AUGUST 21.

The following Papers were read :—

1. *The Origin and Nature of the γ Rays from Radium. By* Professor Sir E. Rutherford, *F.R.S.*

2. *The Distribution in Space of the Stars near the North Pole. By* Dr. F. W. Dyson, *F.R.S.*

3. *The Action of the Juice of* Euphorbia peplus *on a Photographic Plate. By* J. M. Petrie *and* H. G. Chapman.

The dried milky juice of *Euphorbia peplus* acts on a sensitive photographic plate in the dark. If a photographic plate, separated by a space of 3 mm., is exposed for fourteen days to the dried juice spread in the form of letters on glass, sharp images of the letters appear as positive impressions on the plate on development in the ordinary way. Faint images are formed by exposures for such short periods as twenty-four hours, and deeper impressions, but still sharp and well-defined, by exposures up to thirty-one days. The impressions on the plate are more marked when the separation is diminished to 1 mm., and no impression appears when the separation is increased to 12 mm. The images are characteristically well defined, though there is slight diffusion around each letter.

If a piece of black paper, impervious to light, be inserted between the letters and the plate, the images appear as well defined as when the paper is absent. The intervention of paraffined tissue paper fails to prevent the appearance of the image on the plate. Images are seen when thin aluminium foil and gold leaf are used to separate the plate from the letters. The impression can be obtained through thin sheet glass. When a strong current of air is passed between the letters and the plate during the exposure, the image appears sharp and no evidence of diffusion in the direction of the current can be made out.

On examining the dried juice with a sulphide screen no scintillation of particles can be seen. On testing the dried juice in a gold leaf electroscope there is no apparent increase in the rate of discharge of ionised gases. With a sensitive electrometer no action of the dried juice on ionised air could be detected.

On heating the dried juice, the photographic action is not diminished after several hours' heating to 200° C. When charred to a black mass the juice has a diminished action on the plate, and when incinerated to a white ash the ash retains a feeble action.

This photographic action has been noted with all specimens of *Euphorbia peplus* examined by us from many localities, some at least a hundred miles apart. The dried juice retains its action unchanged, so that the original sample, dried and mounted five years ago, is as active as ever.

The juices of many other species of Euphorbia, and of other plants with similar latex-bearing tubes, have no comparable action on the photographic plate.

4. *Photo-electric Effect in Selenium. By* Professor O. U. Vonwiller.

5. *The Pressure upon the Poles of a Carbon Arc. By* Professor W. G. Duffield.

6. *The Attractions of Ellipsoidal Shells. By* Professor A. Gray, *F.R.S.*

MONDAY, AUGUST 24.

The following Papers and Reports were read:—

1. *Discontinuities in Meteorological Phenomena. By* Professor H. H. Turner, *F.R.S.*

2. *The Oblate Shape of the Stellar System. By* Professor A. S. Eddington, *F.R.S.*

3. *An Absolute Determination of the Thermal Conductivity of Air. By* E. O. Hercus *and* T. H. Laby.

4. *The Nature of γ Rays. By* T. H. Laby *and* W. Stuart.

5. *Length and Electrical Resistance of Steel Tapes. By* T. H. Laby *and* G. E. Adams.

6. *A Map of the Principal Earthquake Origins of the S.W. Pacific. By* G. Hogben.

7. *Report on the Investigation of the Upper Atmosphere.—See* Reports, p. 69.

8. *Report on the International Tables of Physical and Chemical Constants.*

9. *Report on the Calculation of Mathematical Tables.*—See Reports, p. 75.

10. *Report on the Disposal of Copies of the Binary Canon.*—See Reports, p. 102.

11. *Interim Report on Radiotelegraphic Investigations.*—See Reports, p. 70.

TUESDAY, AUGUST 25.

Joint Meeting with Section G (Engineering).

Discussion on Wireless Telegraphy. Opened by Sir OLIVER LODGE, *F.R.S.*

The following Papers were then read in Section A :—

1. *Some Measurements of the Wave-length in Air of Electrical Vibrations associated with a Thin Straight Terminated Rod. By* Professor J. A. POLLOCK.

2. *High-Frequency Spectra. By* H. G. J. MOSELEY.

3. *On the Scattering of Light by Small and Large Particles of Conducting and Non-conducting Substances. By* Professor ALFRED W. PORTER, *F.R.S., and* E. TALBOT PARIS, *B.Sc.*

The work summarised herein is a continuation of an investigation by Porter and Keen[1] on the diffraction of light by particles comparable with the wave-length. In that work the scattering was produced by a sulphur suspension, and observations were restricted to the transmitted light. In the present paper the degree of polarisation has been determined (by means of a double-image prism and nicol) for the light scattered in different directions; and suspensions of silver and copper have been investigated as well as suspensions of sulphur. The metallic suspensions were made by the method of Pieroni,[2] which we have found to give stable suspensions.

The results for sulphur particles show a good general agreement with the theoretical values calculated by Lord Rayleigh,[3] but exact comparison is not possible owing to the difficulty of determining the size of the particles. In the case of the silver particles comparison with theory is easier, because the total amount of silver present can be so readily determined chemically, the number of particles per unit volume can be counted, and thence their size can be calculated. Measurements of the size were also made by Perrin's method, i.e., by counting the number of particles in each of two layers a small vertical distance apart, and attributing the difference (as in an atmosphere of gas) to the total weight of particles in the intervening space. Both methods give practically the same results.

Complete curves have been obtained for the polarisation for different-sized particles in different directions. Mention will be made here only of the direction of maximum polarisation for silver suspensions for light of wave-length 550$\mu\mu$. This is shown in the following table :—

Diameter of particles.	Direction of max. polarisation.	Relative electric conductivity.
$\mu\mu$		
80	90°	—
98	90°	2·96
108	98°·36′	3·70
131	109°·54′	4·12
164	113°·36′	—
310	130°·30′	—

[1] *Proc. Roy. Soc.* A, Vol. 89, 1914.
[2] *Gazetta,* 43 (1), 197 (1913).
[3] *Proc. Roy. Soc.* A, Vol. 84, 25 (1910).

According to J. J. Thomson,[4] the direction of maximum polarisation for perfectly conducting particles should make 120° with the incident light. From the above table it appears that for very small particles this angle is 90°, as it would be for *dielectric* particles (a fact which we find was previously observed by Professor R. Threlfall[5]), but that it increases as the diameter of the particle increases to a value above the theoretical limit.

Measurements were also made of the electrical conductivity of the suspensions. Since the average distance between the particles was about 100 times their diameter, Maxwell's theory of the conductivity of compound media is applicable. The conductivity was measured in every case for concentrations containing the same amount of silver and other bodies per unit volume, but differing only in the size of the particles. In these circumstances the conductances should be the same unless there is a difference in the conductivity of the silver particles. It will be seen that the conductivity of the mixture increases as the particles increase in size. It would seem, therefore, that the anomalous behaviour of the silver is due to a real change in resistance with size, and is not simply a consequence of the fact that Thomson's theory is limited to the cases for which the conductivity is sufficiently large.

No numerical calculation has previously been made for large particles. By transferring Thomson's equations so as to express the result in terms of the same functions which have been calculated by Lord Rayleigh for fairly large value of the argument, his work becomes available for the present problem; and one of us (E. T. P.) has calculated the degree of polarisation of the light scattered in different directions for perfectly conducting particles for which $\frac{2\pi \times \text{radius}}{\lambda}$ = unity, when λ = wave length of the light. The maximum polarisation corresponds to an angle for about 108°. The value indicated by our experiments lies between 110° and 120°, but further experiments are necessary to fix it more exactly.

It is not difficult to suggest a reason for the diminution of the conductivity with size. Separated molecules, as in a vapour, are perfectly non-conducting; we conclude that there are then no free electrons. Aggregation of molecules of silver as in a solid gives rise to free electrons (and consequent conductivity) owing to the mutual action of the molecules upon one another. In small particles the number of free electrons may be proportionately less than for silver in mass.

It must not be forgotten, however, that a colloid particle in its medium is surrounded by a double layer consisting of polarised molecules of the medium, and it is quite possible that it is this polarised layer of a dielectric medium which modifies the optical properties of the silver.

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4. *On the Viscosities of the Halogens in the Gaseous State.* *By* A. O. RANKINE, *D.Sc.*

In this paper various methods which have been used for measuring the viscosities of the vapours of Chlorine, Bromine, and Iodine at a number of different temperatures were described.

The relations between the viscosities of these three gases were discussed. The laws are similar to those which the author has previously shown to apply to the group of inert gases.

DEPARTMENT OF MATHEMATICS.

1. *Symbolic Solution of Linear Partial Differential Equations of the Second Order.* *By* T. W. CHAUNDY, *M.A.*

STATEMENT OF RESULTS.

Take equation in form $\frac{\delta^2 z}{\delta x \delta y} + \alpha \frac{\delta z}{\delta x} + \beta \frac{\delta z}{\delta y} + \gamma z = 0$, where α, β, γ denote functions of x, y. The invariants h, k are $\frac{\delta \alpha}{\delta x} + \alpha\beta - \gamma = h$, $\frac{\delta \beta}{\delta y} + \alpha\beta - \gamma = k$.

[4] *Recent Researches in Electricity and Magnetism*, p. 449. [5] *Phil. Mag.*, 1894.

Introduce symbolic operators $\Delta_y \equiv (-\int (k-h)dx\alpha + \frac{1}{\delta_x} h)$

$$\Delta_x \equiv (-\int^y (h-k)dy\beta + \frac{1}{\delta_y} k)$$

$$\Theta_y \equiv 1 + \frac{1}{\delta y}\Delta_y + \left(\frac{1}{\delta_u}\Delta_y\right)^2 + \dots,$$

$$\Theta_x \equiv 1 + \frac{1}{\delta x}\Delta_x + \left(\frac{1}{\delta_x}\Delta_x\right)^2 + \dots$$

Then a symbolic solution appears as

$$e^{-\int^x \beta.dx}\Theta_y\phi(x) + e^{-\int^y \alpha.dy}\Theta_x\psi(y)$$

where ϕ, ψ are arbitrary functions of their arguments. Here the arbitrary elements enter in an infinite series of their derivative.

We may deduce a form of solution in which ϕ, ψ enter in finite terms, namely—

$$Z = e^{-\int^x \beta dx}\int^y \phi(t)\Theta_y\left[e^{t(\delta_y - \Delta_y)}1\right]_{y=0} dt$$

$$+ e^{-\int^y \alpha.dx}\int^x \psi(t).\Theta_x\left[e^{t(\delta_x - \Delta_x)}1\right]_{x=0} dt$$

Applying these results to the equation $S = z$ we obtain a solution

$$z = \int_0^y \phi(t).J\{(y-t)x\}dt + \int_0^x \psi(t).J\{(x-t)y\}dt + C.J(xy)$$

where C is a constant and $J(u) = 1 + \frac{u}{(1!)^2} + \frac{u^2}{(2!)^2} + \dots \frac{u^n}{(n!)^2} + \dots$

2. *Properties of Algebraic Numbers Analogous to Certain Properties of Algebraic Functions.* *By* Professor J. C. Fields, *F.R.S.*

Suppose ϵ to be a root of an integral algebraic equation $f(x) = 0$ of degree n in x and irreducible in the domain of the rational numbers. Where p is a prime $f(x)$ may, however, happen to be reducible in the domain of the p-adic numbers. Assuming the number of the irreducible p-adic factors to be r we write $f(x) = f_1(x) \dots f_r(x)$, where the coefficients of the powers of x in $f_1(x), \dots f_r(x)$ are p-adic numbers.

Consider $R(\epsilon)$ any rational function of ϵ. It may be written as a polynomial of degree $n-1$ in ϵ and satisfies an algebraic equation $F(X) = 0$, where we have $F(X) = F_1(X) \dots F_r(X)$. The factors $F_1(X), \dots F_r(X)$ here have p-adic coefficients and are co-ordinated with the factors $f_1(x), \dots f(x)$ of $f(x)$. The degrees of the factors $f_1(x), \dots f_r(x)$, as also those of the factors $F_1(X), \dots, F_r(X)$ will be certain integers $n_1 \dots, n_r$ respectively. The constant terms in the factors $F_1(X), \dots F_r(X)$ we name the *p-adic partial norms* of $R(\epsilon)$. The order numbers relative to p of the p-adic partial norms of $R(\epsilon)$ divided by $n_1, \dots,$

n_r respectively we call the *orders of coincidence* of $R(\epsilon)$ with the p-adic factors of the fundamental equation $f(x) = 0$.

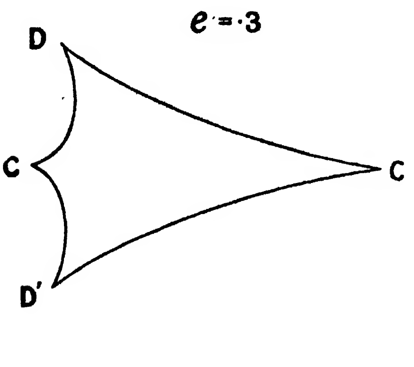
The coefficient of ϵ^{n-1} in the number $R(\epsilon)$ we call its *principal coefficient.* The orders of coincidence of such number relative to the prime p will be integral multiples of certain numbers $1/\nu_1, \ldots, 1/\nu_r$, where $\nu_1, \ldots, \nu_r$ are factors of $n_1, \ldots, n_r$ respectively. We consider the aggregate of numbers $R(\epsilon)$ possessing an assigned set of orders of coincidence relative to p. The necessary and sufficient condition that the principal coefficient in the aggregate be integral is that the assigned orders of coincidence have a certain set of values. This particular set of orders of coincidence defines *adjointness* relative to the prime p with regard to the fundamental equation.

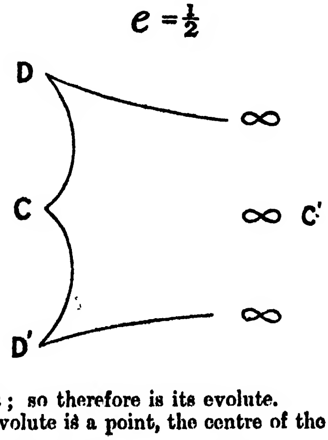
If we start out from a sufficiently general rational form $R(\epsilon)$ with its coefficients represented in p-adic form and impose on it the conditions requisite in order that it may possess a certain set of orders of coincidence relative to the prime p, these conditions take the form of a succession of independent congruences relative to the prime p imposed on the coefficients of the powers of p in the p-adic coefficients of the powers of ϵ. We find a formula for the number of these conditions. We also assign sets of orders of coincidence $\tau_1^{(p)}, \ldots \tau_{r_p}^{(p)}$ corresponding to all primes p, these orders of coincidence being 0 with the exception of a finite number among them. Such a system of orders of coincidence we call a *basis of coincidences.* We define *complementary adjoint bases of coincidences* and derive the analogue of the complementary theorem in the theory of the algebraic functions.

3. *The Green's Function for the Equation* $\nabla^2 u + k^2 u = 0$. *By* Professor H. S. Carslaw.

4. *The Evolute of the Limaçon.* *By* Professor W. H. H. Hudson, *M.A., LL.M.*

The equation of the Limaçon is taken in the form $r = a\,(1 + e\cos\theta)$, a will be made 1, and the abbreviations used $1 - e^2 = f$, $1 - 4e^2 = k$, $e\,(1+e)\,/\,(1+2e) = c$, $e\,(1-e)\,/\,(1-2e) = c'$.





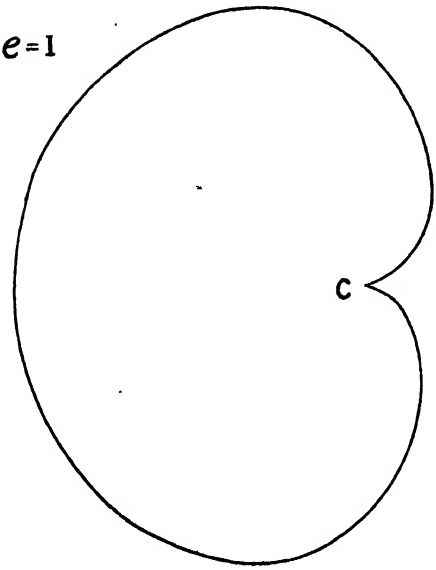
The Limaçon is symmetrical about the x- axis; so therefore is its evolute.

(1) When $e = 0$, the Limaçon is a circle; the evolute is a point, the centre of the circle.

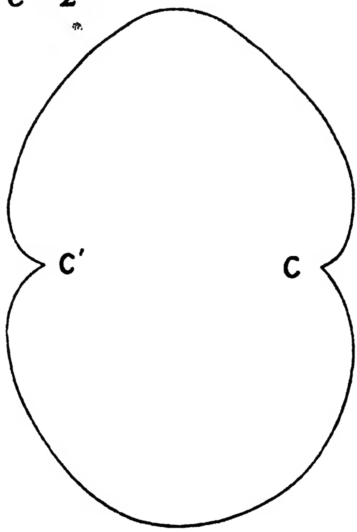
(2) When $\frac{1}{2} > e > 0$, the evolute is a closed curve with four cusps pointing outwards. These cusps are $D, (ef, e^2\sqrt{f})$, $D', (ef, -e^2\sqrt{f})$, $C, (c, 0)$, $C', (c', 0)$. All four lie on the circle $y^2 + (x-c)(x-c') = 0$. As e increases, this at first star-like figure grows larger, the total height approaches $\sqrt{3}/4$ as e approaches $\frac{1}{2}$, the breadth (parallel to the x- axis) increases indefinitely.

(3) When $e = \frac{1}{2}$, c' becomes ∞, the height becomes $\sqrt{3}/4$. The cusp C' is at

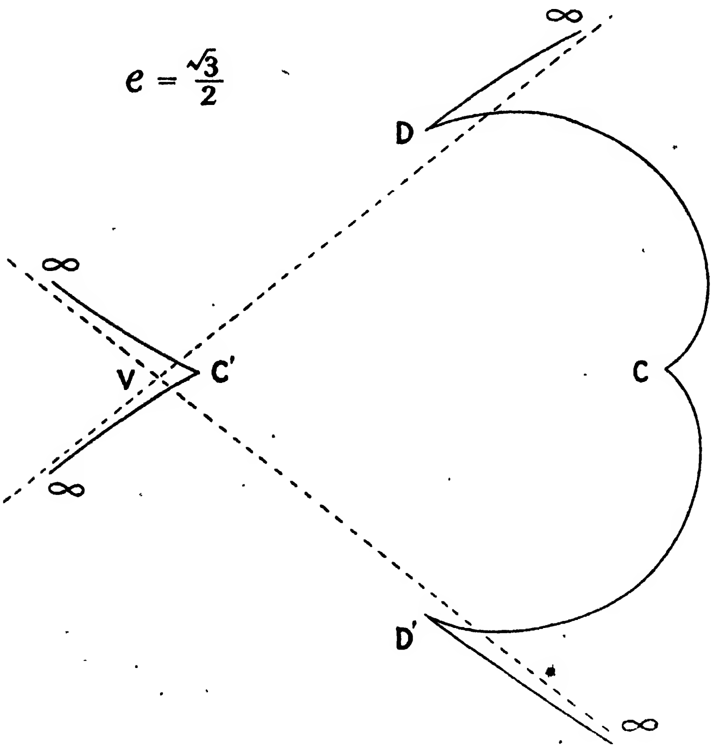
$e = 1$



$e = 2$



$e = \frac{\sqrt{3}}{2}$



infinity, the other three lie on the straight line $x = 3/8$, which may be regarded as a circle of infinite radius; the x- axis may be regarded as two coincident asymptotes.

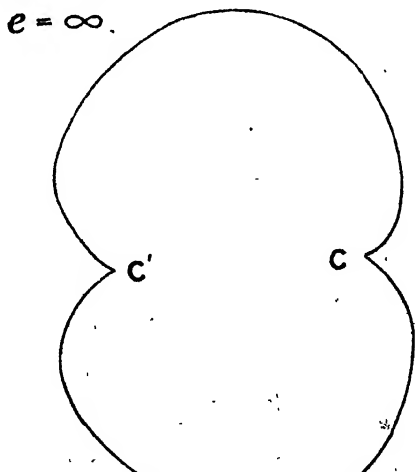
(4) When $1 > e > \frac{1}{2}$, there are two asymptotes making equal angles with the x- axis. As e increases from $\frac{1}{2}$ to 1 the angle between the asymptotes increases from 0° to 180°, their intersection, V, moves from $(-\infty, 0)$ to the origin; the cusp C′ precedes V from $(-\infty, 0)$ to $(0, 0)$; the distance D D′ increases to a maximum $4\sqrt{3}/9$ when $e = \sqrt{(2/3)}$, and then dwindles to 0.

(5) When $e = 1$, the Limaçon is a cardioid, the evolute is also a cardioid; it passes through the origin, its cusp C′ is at $(2/3, 0)$: the three cusps C′, D, D′, coincident at the origin, become a simple point on the cardioid.

(6) When $e > 1$, the cusps D, D′ have disappeared, the cusps C, C′ point inwards, the curve is closed, the shape of the curve does not change much as e increases, the distance C C′ diminishes from 2/3 to $\frac{1}{2}$, the total height (parallel to the y- axis) increases from $\sqrt{3}/2$ to 1, the breadth, now less than the height, diminishes from 3/4 to $1/\sqrt{2}$.

(7) When $e = \infty$, the evolute is altogether at infinity; the difference $c - c'$ is found to be finite and equal to $\frac{1}{2}$, likewise the height, 1, the breadth, $1/\sqrt{2}$; the position of the breadth, $\frac{1}{4}/\sqrt{2}$, above and below C C′ enable an illustrative figure to be drawn. It is symmetrical about its central ordinate.

Diagrams are given to illustrate these cases, except (1), which needs no diagram.
(2) $e = \cdot 3$, the star elongated.
(3) $e = \frac{1}{2}$, with three cusps in a straight line.
(4) $e = \frac{1}{2}\sqrt{3}$, with the four cusps at the corners of a square.
(5) $e = 1$, where three cusps are hidden in one point.
(6) $e = 2$, the evolute of the Trisectrix.
(7) $e = \infty$, with double symmetry.



The equation of the evolute is

$$k^3\left\{y^2+(x-c)(x-c')\right\}^3+27e^2y^2(y^2+x^2-e\,a\,x)^2=0.$$

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5. On the Algebraic Theory of Modular Systems (or Modules of Polynomials). By F. S. MACAULAY, *M.A.*

The theory of modules of polynomials is still only in its infancy, although [illegible] an age of 135 years, its origin dating from the 'Théorie [illegible]ations Algébriques,' par M. Bézout, de l'Académie Royale des

Sciences, M.DCC.LXXIX. Its status and importance were made apparent by Kronecker's theory of Divisor Systems.

The central problem (of which no satisfactory solution has yet been given) is to find one or several ways of expressing the complete conditions that a polynomial F must satisfy in order that it may be capable of taking the form

$$F = X_1F_1 + X_2F_2 + \ldots + X_kF_k,$$

where $F_1, F_2, \ldots, F_k$ are given polynomials (in general non-homogeneous) in n variables $x_1, x_2, \ldots, x_n$, and $X_1, X_2, \ldots, X_k$ are any polynomials in the same variables, not given. The whole system of polynomials F is called a *module* (of polynomials), and is regarded as a single entity or class, and is symbolised by a letter M. Each F is called a *member* of M, and the set of polynomials $F_1, F_2, \ldots, F_k$ is called a *basis* of M.

A module M is considered from its two conjugate aspects, viz. (i) its content as represented by its members, and (ii) its content as represented by its modular equations, *i.e.*, the linear equations which are identically satisfied by the coefficients of each and every member F of M. (ii) has received little attention hitherto. Either (i) or (ii) gives a complete representation of the module; but the difficulty is to obtain (ii) from (i) and *vice versa*. In combination (i) and (ii) give a very complete view of a module and afford together a simple answer to most general questions. Thus the members of the G.C.M. of any number of modules consist of all the members of all the modules; the modular equations of the L.C.M. of any number of modules consist of all the modular equations of all the modules; the members of the product MM′ of two modules M and M′ can be obtained at once from the members of M and M′; and the modular equations of a residual M/M′ can be obtained at once from the modular equations of M and the members of M′.

The most important types of modules were considered; these are the unmixed module, prime module (corresponding to a prime number in arithmetic), primary module (corresponding to a power of a prime in arithmetic), simple module (that is, a module containing one point only), module of the principal class, perfect module, and closed module. The method of obtaining the modular equations from a basis of the module was discussed, and also the resolution of a module into primary modules.

6. *A Theory of Double Points.* *By* F. S. MACAULAY, *M.A.*

BRISBANE.

FRIDAY, AUGUST 22.

Professor E. W. Brown, F.R.S., Vice-President of the Section, delivered the following Address :—

To one who has spent many years over the solution of a problem which is somewhat isolated from the more general questions of his subject, it is a satisfaction to have this opportunity for presenting the problem as a whole instead of in the piecemeal fashion which is necessary when there are many separate features to be worked out. In doing so, I shall try to avoid the more technical details of my subject as well as the temptation to enter into closely reasoned arguments, confining myself mainly to the results which have been obtained and to the conclusions which may be drawn from them.

In setting forth the present status of the problem, another side of it gives one a sense of pleasure. When a comparison between the work of the lunar theorist and that of the observer has to be made, it is necessary to take into consideration the facts and results obtained by astronomers for purposes not directly connected with the moon : the motions of the earth and planets, the position of the observer, the accuracy of star catalogues, the errors of the instruments used for the measurement of the places of celestial objects, the personality of the observers—

all these have to be considered; in fact, almost every one of the departments of the astronomy of position must be drawn upon to furnish necessary data. The time has now arrived when it may perhaps be possible to repay in some measure the debt thus contracted by furnishing to the astronomer, and perhaps also to the student of geodesy and, if I may coin a word, of selenodesy, some results which can be deduced more accurately from a study of the moon's motion than in any other way. A long-continued exploration with few companions which ultimately leads to territories where other workers have already blazed paths gives the impression of having emerged from the thick jungle into open country. The explorer can once more join forces with his brother astronomers. He can judge his own results more justly and have them judged by others. If, then, an excuse be needed for overstepping the limits which seem, by silent consent, to have been imposed on those who devote themselves to lunar problems, it consists in a desire to show that these limits are not necessary and that a study of the motion of the moon can be of value and can contribute its share to the common funds of astronomy.

The history of the motion of the moon has been for more than two centuries a struggle between the theorists and the observers. Ever since the publication of the 'Principia' and the enunciation of the law of gravitation by Isaac Newton, a constant effort has been maintained to prove that the moon, like the other bodies of the solar system, obeyed this law to its farthest consequences. While the theory was being advanced, the observers were continually improving their instruments and their methods of observing, with the additional advantage that their efforts had a cumulative effect: the longer the time covered by their observations, the more exact was the knowledge obtained. The theorist lacked the latter advantage: if he started anew he could only use the better instruments for analysis provided by the mathematician. He was always trying to forge a plate of armour which the observer with a gun whose power was increasing with the time could not penetrate. In the struggle the victory rarely failed to rest with the observer. Within the last decade we theorists have made another attempt to forge a new plate out of the old materials; whether we have substantially gained the victory must rest partly on the evidence I have to place before you to-day and partly on what the observer can produce in the near future.

There are three well-defined periods in the history of the subject as far as a complete development of the moon's motion is concerned. From the publication of the 'Principia' in 1687, when Newton laid down the broad outlines, until the middle of the eighteenth century, but little progress was made. It seems to have required over half-a-century for analysis by symbols to advance sufficiently far for extensive applications to the problems of celestial mechanics. Clairaut and d'Alembert both succeeded in rescuing the problem from the geometrical form into which Newton had cast it and in reducing it to analysis by the methods of the calculus. They were followed by Leonard Euler, who in my opinion is the greatest of all the successors of Isaac Newton as a lunar theorist. He initiated practically every method which has been used since his time, and his criticisms show that he had a good insight into their relative advantages. A long roll of names follows in this period. It was closed by the publication of the theories of Delaunay and Hansen and the tables of the latter, shortly after the middle of the nineteenth century. From then to the end of the century the published memoirs deal with special parts of the theory or with its more general aspects, but no complete development appeared which could supersede the results of Hansen.

My own theory, which was completed a few years ago, is rather the fulfilment to the utmost of the ideas of others than a new mode of finding the moon's motion. Its object was severely practical—to find in the most accurate way and by the shortest path the complete effect of the law of gravitation applied to the moon. It is a development of Hill's classic memoir of 1877. Hill in his turn was indebted to some extent to Euler. His indebtedness would have been greater had he been aware of a little-known paper of the latter, 'Sur la Variation de la Lune,' in which the orbit, now called the variation orbit, is obtained, and its advantages set forth in the words: 'Quelque chimérique cette question j'ose assurer que, si l'on réussissoit à en trouver une solution parfaite on ne trouveroit presque plus de difficulté pour déterminer le vrai mouvement de la Lune réelle.

Cette question est donc de la dernière importance et il sera toujours bon d'en approfondir toutes les difficultés, avant qu'on en puisse espérer une solution complète.'

In the final results of my work the development aims to include the gravitational action of every particle of matter which can have a sensible effect on the moon's motion, so that any differences which appear between theory and observation may not be set down to want of accuracy in the completeness with which the theory is carried out. Every known force capable of calculation is included.

So much for the theory. Gravitation, however, is only a law of force: we need the initial position, speed, and direction of motion. To get this with sufficient accuracy no single set of observations will serve; the new theory must be compared with as great a number of these as possible. To do this directly from the theory is far too long a task, and, moreover, it is not necessary. In the past every observation has been compared with the place shown in the 'Nautical Almanac' and the small differences between them have been recorded from day to day. By taking many of these differences and reducing them so as to correspond with differences at one date, the position of the moon at that date can be found with far greater accuracy than could be obtained through any one observation. At the Greenwich Observatory the moon has been observed and recorded regularly since 1750. With some 120 observations a year, there are about 20,000 available for comparison, quite apart from shorter series at other observatories. Unfortunately these observations are compared with incorrect theories, and, in the early days, the observers were not able to find out, with the accuracy required to-day, the errors of their instruments or the places of the stars with which the moon was compared. But we have means of correcting the observations, so that they can be freed from many of the errors present in the results which were published at the time the observations were made. We can also correct the older theories. They can be compared with the new theory and the differences calculated: these differences need not even be applied to the separate observations, but only to the observations combined into properly chosen groups. Thus the labour involved in making use of the earlier observations is much less than might appear at first sight.

For the past eighteen months I have been engaged in this work of finding the differences between the old theories and my own, as well as in correcting those observations which were made at times before the resources of the astronomer had reached their present stage of perfection. I have not dealt with the observations from the start: other workers, notably Airy in the last century and Cowell in this, have done the greater part of the labour. My share was mainly to carry theirs a stage further by adopting the latest theory and the best modern practice for the reduction of the observations. In this way a much closer agreement between theory and observation has been obtained, and the initial position and velocity of the moon at a given date are now known with an accuracy comparable with that of the theory. I shall shortly return to this problem and exhibit this degree of accuracy by means of some diagrams which will be thrown on the screen.

I have spoken of the determination of these initial values as if it constituted a problem separate from the theory. Theoretically it is so, but practically the two must go together. The increase in accuracy of the theory has gone on successively with increase in accuracy of the determination of these constants. We do not find, with a new theory, the new constants from the start, but corrections to the previously adopted values of these constants. In fact, all the problems of which I am talking are so much inter-related that it is only justifiable to separate them for the purposes of exposition.

Let us suppose that the theory and these constants have been found in numerical form, so that the position of the moon is shown by means of expressions which contain nothing unknown but the time. To find the moon's place at any date we have then only to insert that date and to perform the necessary numerical calculations. This is not done directly, on account of the labour involved. What are known as 'Tables of the Moon's Motion' are formed. These tables constitute an intermediate step between the theory and the positions of the moon which are printed in the 'Nautical Almanac.' Their sole use and necessity is the abbreviation of the work of calculation

required to predict the moon's place from the theoretical values which have been found. For this reason, the problem of producing efficient tables is not properly scientific: it is mainly economic. Nevertheless, I have found it as interesting and absorbing as any problem which involves masses of calculation is to those who are naturally fond of dealing with arithmetical work. My chief assistant, Mr. H. B. Hedrick, has employed his valuable experience in helping me to devise new ways of arranging the tables and making them simple for use.

A table is mainly a device by which calculations which are continually recurring are performed once for all time, so that those who need to make such calculations can read off the results from the table. In the case of the moon, the tables go in pairs. Each term in the moon's motion depends on an angle, and this angle depends on the date. One table gives the value of the angle at any date (a very little calculation enables the computer to find this), and the second table gives the value of the term for that angle. As the same angles are continually recurring, the second table will serve for all time.

We can, however, do better than construct one table for each term. The same angle can be made to serve for several terms and consequently one table may be constructed so as to include all of them. In other words, instead of looking out five numbers for five separate terms, the computer looks out one number which gives him the sum of the five terms. The more terms we can put into a single table the less work for the astronomer who wants the place of the moon, and therefore the more efficient the tables. A still better device is a single table which depends on two angles, known as a double-entry table; many more terms can usually be included in this than in a single-entry table. The double interpolation on each such table is avoided by having one angle the same for many double-entry tables and interpolating for that angle on the sum of the numbers extracted from the tables.

The problem of fitting the terms into the smallest number of tables is a problem in combinations—something like a mixture of a game at chess and a picture-puzzle, but unlike the latter in the fact that the intention is to produce ease and simplicity instead of difficulty. This work of arrangement is now completed and, in fact, about five-sixths of the calculations necessary to form the tables are done; over one-third of the copy is ready for the printer, but, owing to the large mass of the matter, it will take from two to three years to put it through the press. The cost of performing the calculations and printing the work has been met from a fund specially set aside for the purpose by Yale University.

A few statistics will perhaps give an idea of our work. Hansen has 300 terms in his three co-ordinates, and these are so grouped that about a hundred tables are used in finding a complete place of the moon. We have included over 1,000 terms in about 120 tables, so that there are on the average about eight terms per table. [In one of our tables we have been able to include no less than forty terms.] Each table is made as extensive as possible in order that the interpolations—the bane of all such calculations—shall be easy. The great majority of them involve multiplications by numbers less than 100. There are less than ten tables which will involve multiplications by numbers between 100 and 1,000 and none greater than the latter number. The computer who is set to work to find the longitude, latitude, and parallax of the moon will not need a table of logarithms from the beginning to the end of his work. The reason for this is that all multiplications by three figures or less can be done by Crelle's well-known tables or by a computing machine. But Mr. Hedrick has devised a table for interpolation to three places which is more rapid and easy than either of these aids. It is, of course, of use generally for all such calculations, and arrangements are now being made for the preparation and publication of his tables. The actual work of finding the place of the moon from the new lunar tables will, I believe, not take more time—perhaps less—than from Hansen's tables, as soon as the computer has made himself familiar with them. Fortunately for him, it is not necessary to understand the details of their construction: he need only know the rules for using them.

I am now going to show by means of some diagrams the deviations of the

moon from its theoretical orbit, in which, of course, errors of observation are included. The first two slides exhibit the average deviation of the moon from its computed place for the past century and a half in longitude.[1] The averages are taken over periods of 414 days and each point of the continuous line shows one such average. The dots are the results obtained by Newcomb from occultations; the averages for the first century are taken over periods of several years, and in the last sixty years over every year. In both cases the same theory and the same values of the constants have been used. Only one empirical term has been taken out—the long-period fluctuation found by Newcomb having a period of 270 years and a co-efficient of 13″. I shall show the deviations with this term included, in a moment.

The first point to which attention should be drawn is the agreement of the results deduced from the Greenwich meridian observations and those deduced from occultations gathered from observatories all over the world. There can be no doubt that the fluctuations are real and not due to errors of observation. A considerable difference appears about 1820, for which I have not been able to account, but I have reasons for thinking that the difference is mainly due to errors in the occultations rather than in the meridian values. In the last sixty years the differences become comparatively small, and the character of the deviation of the moon from its theoretical orbit is well marked. This deviation is obviously of a periodic character, but attempts to analyse it into one or two periodic terms have not met with success; the number of terms required for the purpose is too great to allow one to feel that they have a real existence, and that they would combine to represent the motion in the future. The straight line character of the deviations is a rather marked peculiarity of the curves.

The actual deviations on a smaller scale are shown in the next slide; the great empirical term has here been restored and is shown by a broken line. The continuous line represents the Greenwich meridian observations; the dots are Newcomb's results for the occultations before 1750, the date at which the meridian observations begin. With a very slight amount of smoothing, especially since 1850, this diagram may be considered to show the actual deviations of the moon from its theoretical orbit.

The next slide shows the average values of the eccentricity and of the position of the perigee.[2] The deviations are those from the values which I have obtained. It is obvious at once that there is little or nothing systematic about them; they may be put down almost entirely to errors of observation. The diminishing magnitude of the deviations as time goes on is good evidence for this; the accuracy of the observations has steadily increased. The coefficient of the term on which the eccentricity depends is found with a probable error of 0″·02, and the portion from 1750 to 1850 gives a value for it which agrees with that deduced from the portion 1850 to 1901 within 0″·01. The eccentricity is the constant which is now known with the highest degree of accuracy of any of those in the moon's motion. For the perigee there was a difference from the theoretical motion which would have caused the horizontal average in the curve to be tilted up one end over 2″ above that at the other end. I have taken this out, ascribing it to a wrong value for the earth's ellipticity; the point will be again referred to later. The actual value obtained from the observations themselves has been used in the diagram, so that the deviations shown are deviations from the observed value.

The next slide shows the deviations of the mean inclination and the motion of the node, as well as of the mean latitude from the values deduced from the observations.[3] In these cases the observations only run from 1847 to 1901. It did not seem worth while to extend them back to 1750 for it is evident that the errors are mainly accidental, and the mean results agreed so closely with those obtained by Newcomb from occultations that little would have been

[1] *Monthly Notices R.A.S.*, vol. 73, plate 22.

[2] Tables II., III. of a Paper on 'The Perigee and Eccentricity of the Moon,' *Monthly Notices R.A.S.*, March 1914.

[3] 'The Mean Latitudes of the Sun and Moon,' *Monthly Notices R.A.S.* Jan. 1914; 'The Determination of the Constants of the Node, the Inclination, the Earth's Ellipticity, and the Obliquity of the Ecliptic,' *ib.* June 1914.

gained by the use of the much less accurate observations made before 1847. The theoretical motion of the node differs from its observed value by a quantity which would have tilted up one end of the zero line about 0″·5 above the other; the hypothesis adopted in the case of the perigee will account for the difference.

The mean latitude curve is interesting. It should represent the mean deviations of the moon's centre from the ecliptic; but it actually represents the deviations from a plane 0″·5 below the ecliptic. A similar deviation was found by Newcomb. Certain periodic terms have also been taken out. The explanation of these terms will be referred to directly.

The net result of this work is a determination of the constants of eccentricity, inclination, and of the positions of the perigee and node with practical certainty. The motions of the perigee and node here agree with their theoretical values when the new value of the earth's ellipticity is used. The only outstanding parts requiring explanation are the deviations in the mean longitude. If inquiry is made as to the degree of accuracy which the usual statement of the gravitation law involves, it may be said that the index which the inverse square law contains does not differ from 2 by a fraction greater than 1/400,000,000. This is deduced from the agreement between the observed and theoretical motions of the perigee when we attribute the mean of the differences found for this motion and for that of the node to a defective value of the ellipticity of the earth.

I have mentioned the mean deviation of the latitude of the moon from the ecliptic. There are also periodic terms with the mean longitude as argument occurring both in the latitude and the longitude. My explanation of these was anticipated by Professor Bakhuysen by a few weeks. The term in longitude had been found from two series of Greenwich observations, one of 28 and the other of 21 years, by van Steenwijk, and Professor Bakhuysen, putting this with the deviations of the mean latitude found by Hansen and himself, attributed them to systematic irregularities of the moon's limbs.

What I have done is to find (1) the deviation of the mean latitude for 64 years, (2) a periodic term in latitude from observations covering 55 years, and (3) a periodic term in longitude from observations covering 150 years, the period being that of the mean longitude. Further, if to these be added Newcomb's deviations of the mean latitude derived (*a*) from immersions and (*b*) from emersions, we have a series of five separate determinations separate because the occultations are derived from parts of the limb not wholly the same as those used in meridian observations. Now all these give a consistent shape to the moon's limb referred to its centre of mass. This shape agrees qualitatively with that which may be deduced from Franz's figure.

I throw on the screen two diagrammatic representations[4] of these irregularities obtained by Dr. F. Hayn from a long series of actual measures of the heights and depths of the lunar formations. The next slide shows the systematic character more clearly. It is from a paper by Franz.[5] It does not show the character of the heights and depths at the limb, but we may judge of these from the general character of the high and low areas of the portions which have been measured and which extend near to the limbs. I think there can be little doubt that this explanation of these small terms is correct, and if so it supplies a satisfactory cause for a number of puzzling inequalities.

The most interesting feature of this result is the general shape of the moon's limb relative to the centre of mass and its relation to the principle of isostasy. Here we see with some definiteness that the edge of the southern limb in general is further from the moon's centre of mass than the northern. Hence we must conclude that the density at least of the crust of the former is less than that of the latter, in accordance with the principle mentioned. The analogy to the figure of the earth with its marked land and sea hemispheres is perhaps worth pointing out, but the higher ground in the moon is mainly on the south of its equator, while that on the earth is north. Unfortunately we know nothing about the other face of the moon. Nevertheless it seems worth while to direct the attention of geologists to facts which may ultimately have some

[4] *Abh. der Math.-Phys. Kl. der Kön Sachs. Ges. der Wiss.*, vols. xxix., xxx.
[5] *Konigsberger Astr. Beob.*, Abth. 38

cosmogonic applications. The astronomical difficulties are immediate: different corrections for meridian observations in latitude, in longitude, on Mösting A, for occultations and for the photographic method, will be required.

I next turn to a question, the chief interest of which is geodetic rather than astronomical. I have mentioned that a certain value of the earth's ellipticity will make the observed motions of the perigee and node agree with their theoretical values. This value is 1/293·7 ±·3. Now Helmert's value obtained from gravity determinations is 1/298·3. The conference of 'Nautical Almanac' Directors in 1911 adopted 1/297. There is thus a considerable discrepancy. Other evidence, however, can be brought forward. Not long ago a series of simultaneous observations at the Cape and Greenwich Observatories was made in order to obtain a new value of the moon's parallax. After five years' work a hundred simultaneous pairs were obtained, the discussion of which give evidence of their excellence. Mr. Crommelin, of the Greenwich Observatory, who undertook this discussion, determined the ellipticity of the earth by a comparison between the theoretical and observed values of the parallax. He found an ellipticity 1/294·4±1·5 closely agreeing with that which I have obtained. Finally, Col. Clarke's value obtained from geodetic measures was 1/293·5. We have thus three quite different determinations ranging round 1/294 to set against a fourth determination of 1/298. The term in the latitude of the moon which has often been used for this purpose is of little value on account of the coefficient being also dependent on the value of the obliquity of the ecliptic: such evidence as it presents is rather in favour of the larger value. I omit Hill's value, obtained from gravity determinations, because it is obviously too large.

Here, then, is a definite issue. To satisfy the observations of the moon in at least three different parts, a value near 1/294 must be used; while the value most carefully found from gravity determinations is 1/298. As far as astronomy is concerned, the moon is the only body for which a correct value of this constant is important, and it would seem inadvisable to use a value which will cause a disagreement between theory and observation in at least three different ways. It is a question whether the conference value should not be changed with the advent of the new lunar tables.

In looking forward to future determinations of this constant, it seems to be quite possible that direct observations of the moon's parallax are likely to furnish at least as accurate a value of the earth's shape as any other method. This can be done, I believe, much better by the Harvard photographic method than by meridian observations. Two identical instruments are advisable for the best results, one placed in the northern and the other in the southern hemisphere from 60° to 90° apart in latitude and as nearly as possible on the same meridian. On nights which are fine at both stations, from fifteen to twenty pairs of plates could be obtained. In a few months it is probable that some 400 pairs might be obtained. These should furnish a value for the parallax with a probable error of about 0″·02 and a value for the ellipticity within half a unit of the denominator 294. It would be still more interesting if the two instruments could be set up on meridians in different parts of the earth. The Cape and a northern observatory, Upsala for example, would furnish one arc; Harvard and Ariquipa or Santiago another. If it were possible to connect by triangulation Australia with the Asiatic continent, a third could be obtained near the meridian of Brisbane. Or, accepting the observed parallax and the earth's ellipticity, we could find by observation the lengths of long arcs on the earth's surface with high accuracy.

In any case, I believe that the time must shortly come when the photographic method of finding the moon's place should be taken up more extensively, whether it be used for the determination of the moon's parallax and the earth's ellipticity or not. The Greenwich meridian observations have been and continue to be a wonderful storehouse for long series of observations of the positions of the sun, moon, planets, and stars. In the United States, Harvard Observatory has adopted the plan of securing continuous photographic records of the sky with particular reference to photometric work. Under Professor Pickering it will also continue the photographic record of the moon's position as long as arrangements can be made to measure the plates and compute the moon's position from them.

In spite of the fact that Harvard Observatory has undertaken to continue for the present the work of photographing the moon's position, I believe that this method should find a permanent home in a national observatory. It has already shown itself capable of producing the accuracy which the best modern observations of Greenwich can furnish, and no higher praise need be given. If this home could be found in the southern hemisphere, and more particularly in Australia, other advantages would accrue.

But we should look for more than this. In an observatory whose first duty might be the securing of the best daily records of the sky, the positions of the sun, stars, planets, a couple of plates of the moon on every night when she is visible would be a small matter. What is needed is an organisation so constructed as to be out of the reach of changing governmental policy with a permanent appropriation and a staff of the highest character removed from all political influences. It could render immense service to astronomers, not only in the Empire but all over the world. The pride which every Englishman feels who has to work with the records of the past furnished by Greenwich would in course of time arise from the work of a similar establishment elsewhere. Those of us who live in a community which, reckoning by the age of nations, is new, know that, in order to achieve objects which are not material, sacrifices must be made; but we also know that such sacrifices are beneficial, not only in themselves, but as exerting an indirect influence in promoting the cause of higher education and of scientific progress in every direction. In saying this I am not advocating the cause of the few, but of the majority; the least practical investigations of yesterday are continually becoming of the greatest practical value to-day.

No address before this section is complete without some speculation and a glance towards the future. I shall indulge in both to some small extent before closing. I have shown you what the outstanding residuals in the moon's motion are: they consist mainly of long period fluctuations in the mean longitude. I have not mentioned the secular changes because the evidence for them does not rest on modern observations but on ancient eclipses, and these are matters too debatable to discuss in the limited time allotted to me for this address. It may be said, however, that the only secular motion which is capable of being determined from the modern observations and is not affected by the discussion of ancient eclipses—namely, the secular motion of the perigee—agrees with its theoretical value well within the probable error. With this remark I pass to the empirical terms.

These unexplained differences between theory and observation may be separated into two parts. First, Newcomb's term of period between 250 and 300 years and coefficient 13″, and, second, the fluctuations which appear to have an approximate period of 60 to 70 years. The former appears to be more important than the latter, but from the investigator's point of view it is less so. The force depends on the degree of inclination of the curve to the zero line or on the curvature, according to the hypothesis made. In either case the shorter period term is much more striking, and, as I have pointed out on several occasions, it is much more likely to lead to the sources of these terms than the longer period. It is also, at least for the last sixty years, much better determined from observation, and is not likely to be confounded with unknown secular changes.

Various hypotheses have been advanced within the last few years to account for these terms. Some of them postulate matter not directly observed or matter with unknown constants; others, deviations of the Newtonian law from its exact expression; still others, non-gravitational forces. M. St. Blancat * examines a variety of cases of intramercurial planets and arrives at the conclusion that such matter, if it exists, must have a mass comparable with that of Mercury. Some time ago I examined the same hypothesis and arrived at similar results. The smallest planet with density four times that of water, which would produce the long inequality, must have a disc of nearly 2″ in its transit across the sun and a still larger planet would be necessary to produce the shorter period terms. But observational attempts, particularly those made by Perrine and Campbell, have always failed to detect any such planet, and Professor Campbell is of the opinion that a body with so large a disc could hardly have been overlooked. If

* *Annales de la Faculté des Sciences de Toulouse*, 1907.

we fall back on a swarm instead of a single body, we replace one difficulty by two. The light from such a swarm would be greater than that from a single body, and would therefore make detection more likely. If the swarm were more diffused we encounter the difficulty that it would not be held together by its own attraction, and would therefore soon scatter into a ring; such a ring cannot give periodic changes of the kind required.

The shading of gravitation by interposing matter, *e.g.* at the time of eclipses, has been examined by Bottlinger.[7] For one reason alone, I believe this is very doubtful. It is difficult to see how new periodicities can be produced; the periods should be combinations of those already present in the moon's motion. The sixty to seventy years' fluctuation stands out in this respect because its period is not anywhere near any period present in the moon's motion or any probable combination of the moon's periods. Indeed Dr. Bottlinger's curve shows this: there is no trace of the fluctuation.

Some four years ago I examined[8] a number of hypotheses. The motions of the magnetic field of the earth and of postulated fields on the moon had to be rejected, mainly because they caused impossible increases in the mean motion of the perigee. An equatorial ellipticity of the sun's mass, combined with a rotation period very nearly one month in length, appeared to be the best of these hypotheses. The obvious objections to it are, first, that such an ellipticity, small as it can be (about 1/20,000), is difficult to understand on physical grounds, and, second, that the rotation period of the nucleus which might be supposed to possess this elliptic shape in the sun's equator is a quantity which is so doubtful that it furnishes no help from observation, although the observed periods are well within the required limits. Dr. Hale's discovery of the magnetic field of the sun is of interest in this connection. Such a field, of non-uniform strength, and rotating with the sun, is mathematically exactly equivalent to an equatorial ellipticity of the sun's mass, so that the hypothesis might stand from the mathematical point of view, the expression of the symbols in words being alone different.

The last-published hypothesis is that of Professor Turner,[9] who assumes that the Leonids have finite mass and that a big swarm of them periodically disturbs the moon as the orbits of the earth and the swarm intersect. I had examined this myself last summer, but rejected it because, although it explained the straight line appearance of the curve of fluctuations, one of the most important of the changes of direction in this curve was not accounted for. We have the further difficulty that continual encounters with the earth will spread the swarm along its orbit, so that the swarm with this idea should be a late arrival and its periodic effect on the moon's motion of diminishing amplitude; with respect to the latter, the observed amplitude seems rather to have increased.

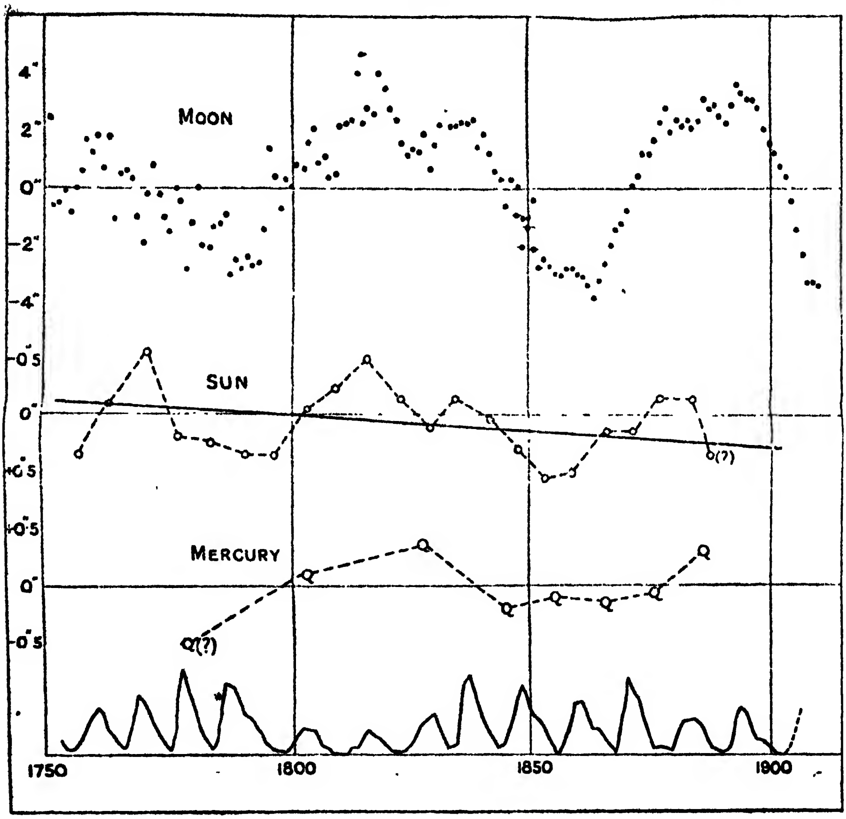
The main objection to all these ideas consists in the fact that they stand alone: there is as yet little or no collateral evidence from other sources. The difficulty, in fact, is not that of finding an hypothesis to fit the facts, but of selecting one out of many. The last hypothesis which I shall mention is one which is less definite than the others, but which does appear to have some other evidence in its favour.

The magnetic forces, mentioned above, were changes in the *directions* of assumed magnetic fields. If we assume changes in the intensities of the fields themselves, we avoid the difficulties of altering portions of the moon's motion other than that of the mean motion. We know that the earth's magnetic field varies and that the sun has such a field, and there is no inherent improbability in attributing similar fields to the moon and the planets. If we assume that variations in the strength of these fields arise in the sun and are communicated to the other bodies of the solar system, we should expect fluctuations having the same period and of the same or opposite phase but differing in magnitude. It therefore becomes of interest to search for fluctuations in the motions of the planets similar to that found in the moon's orbit. The material in available form for this purpose is rather scanty; it needs to be

[7] *Diss.*, Freiburg i. Br., 1912. [8] *Amer. Jour. Sc.*, vol. 29.
[9] *Monthly Notices*, December 1913.

a long series of observations reduced on a uniform plan. The best I know is in Newcomb's 'Astronomical Constants.' He gives there the material for the earth arranged in groups of a few years at a time. The results for Mercury, given for another purpose, can also be extracted from the same place. For Venus and Mars, Newcomb unfortunately only printed the normal equations from which he deduces the constants of the orbit.

On the screen is shown a slide (see below) which exhibits the results for the Earth and Mercury compared with those for the moon. In the uppermost curve are reproduced the minor fluctuations of the moon shown earlier; the second curve contains those of the earth's longitude; the third, those of Mercury's longitude. [By accident the mean motion correction has been left in the Earth curve; the zero line is therefore inclined instead of being



horizontal.] It will be noticed that the scales are different and that the Earth curve is reversed. In spite of the fact that the probable errors of the results in the second and third curves are not much less than their divergencies from a straight line, I think that the correlation exhibited is of some significance. If it is, we have here a force whose period, if period in the strict sense it has, is the same as that of the effect: the latter is not then a resonance from combination with another period. We must therefore look for some kind of a surge spreading through the solar system and affecting planets and satellites the same way but to different degrees.

The lowest curve is an old friend, that of Wolf's sunspot frequency, put there, not for that reason, but because the known connection for the last sixty years between sunspot frequency and prevalence of magnetic disturbance

enables us with fair probability to extend the latter back to 1750. With some change of phase the periods of high and low maxima correspond nearly with the fluctuations above. The eleven-year oscillation is naturally eliminated from the group results for the Earth and Mercury. One might expect it to be present in the lunar curve, but owing to its shorter period we should probably not obtain a coefficient of over half-a-second. Notwithstanding this fact, it is a valid objection to the hypothesis that there is no evidence of it in the moon's motion. Reasons may exist for this: but until the mechanism of the action can be made more definite it is hardly worth while to belabour the point.

The hypothesis presents many difficulties. Even if one is disposed to admit provisionally a correlation between the four curves—and this is open to considerable doubt—it is difficult to understand how, under the electron theory of magnetic storms, the motions of moon and planets can be sensibly affected. I am perhaps catching at straws in attempting to relate two such different phenomena with one another, but when we are in the presence of anomalies which show points of resemblance and which lack the property of analysis into strict periodic sequences some latitude may be permissible.

In conclusion, what, it may well be asked, is the future of the lunar theory now that the gravitational effects appear to have been considered in such detail that further numerical work in the theory is not likely to advance our knowledge very materially? What good purpose is to be served by continuous observation of the moon and comparison with the theory? I believe that the answer lies mainly in the investigation of the fluctuations already mentioned. I have not referred to other periodic terms which have been found because the observational evidence for their real existence rests on foundations much less secure. These need to be examined more carefully, and this examination must, I think, depend mainly on future observations rather than on the records of the past. Only by the greatest care in making the observations and in eliminating systematic and other errors from them can these matters be fully elucidated. If this can be achieved and if the new theory and tables serve, as they should, to eliminate all the known effects of gravitation, we shall be in a position to investigate with some confidence the other forces which seem to be at work in the solar system and at which we can now only guess. Assistance should be afforded by observations of the sun and planets, but the moon is nearest to us and is, chiefly on that account, the best instrument for their detection. Doubtless other investigations will arise in the future. But the solution of the known problems is still to be sought, and the laying of the coping stone on the edifice reared through the last two centuries cannot be a simple matter. Even our abler successors will hardly exclaim, with Hotspur,

> 'By heaven, methinks, it were an easy leap
> To pluck bright honour from the pale-faced moon.'

They, like us and our predecessors, must go through long and careful investigations to find out the new truths before they have solved our difficulties, and in their turn they will discover new problems to solve for those who follow them:—

'For the fortune of us, that are the moon's men, doth ebb and flow like the sea, being governed, as the sea is, by the moon.'

Section B.—CHEMISTRY.

President of the Section.—Professor William J. Pope, M.A., LL.D., F.R.S.

Melbourne.

FRIDAY, AUGUST 14.

The President delivered the following Address:—

The British Association has been firmly established as one of the institutions of our Empire for more than half a century past. The powerful hold which it has acquired probably arises from the welcome which every worker in science extends to an occasional cessation of his ordinary routine—a respite during which the details of the specific inquiry in hand may be temporarily cast aside, and replaced by leisurely discussion with colleagues on the broader issues of scientific progress.

The investigator, continually occupied with his own problems and faced with an ever-increasing mass of technical literature, ordinarily finds little time for reflection upon the real meaning of his work; he secures, in general, far too few opportunities of considering in a philosophical sort of way the past, present, and future of his own particular branch of scientific activity. It is not difficult to form a fairly accurate survey of the position to which Chemistry had attained a generation ago, perhaps even a few years ago; probably no intellect at present existing could pronounce judgment upon the present position of our science in terms which would commend themselves to the historian of the twenty-first century. Doubtless even one equipped with a complete knowledge of all that has been achieved, standing on the very frontier of scientific advance and peering into the surrounding darkness, would be quite incompetent to make any adequate forecast of the conquests which will be made by chemical and physical science during the next fifty years. At the same time, chemical history tells us that progress is the result in large measure of imperfect attempts to appreciate the present and to forecast the future. I therefore propose to lay before you a sketch of the present position of certain branches of chemical knowledge and to discuss the directions in which progress is to be sought; none of us dare cherish the conviction that his views on such matters are correct, but everyone desirous of contributing towards the development of his science must attempt an appreciation of this kind. The importance to the worker and to the subject of free ventilation and discussion of the point of view taken by the individual can scarcely be over-estimated.

The two sciences of Chemistry and Physics were at one time included as parts of the larger subject entitled Natural Philosophy, but in the early part of the nineteenth century they drew apart. Under the stimulus of Dalton's atomic theory, Chemistry developed into a study of the interior of the molecule, and, as a result of the complication of the observed phenomena, progressed from stage to stage as a closely reasoned mass of observed facts and logical conclusions. Physics, less entangled in its infancy with numbers of experimental data which apparently did not admit of quantitative correlation, was developed largely as a branch of applied mathematics; such achievements of the formal

Physics of the last century as the mathematical theory of light and the kinetic theory of gases are monuments to the powers of the human intellect.

The path of Chemistry, as an application of pure logical argument to the interpretation of complex masses of observations, thus gradually diverged from that taken by Physics as the mathematical treatment of less involved experimental data, although both subjects derived their impetus to development from the speculations of genius.

It is interesting to note, however, that during recent years the two sciences, which were so sharply distinguished twenty years ago as to lead to mutual misunderstandings, are now converging. Many purely chemical questions have received such full quantitative study that the results are susceptible to attack by the methods of the mathematical physicist; on the other hand, the intense complication perceived during the fuller examination of many physical problems has led to their interpretation by the logical argument of the chemist because the traditional mathematical mode of attack of the physicist has proved powerless to deal with the intricacies exhibited by the observed facts.

The progress of Chemistry during the last century has been mainly the result of the co-ordination of observed facts in accordance with a series of hypotheses each closely related in point of time to the one preceding it. The atomic theory, as it was enunciated by Dalton in 1803, was a great impetus to chemical investigation, but proved insufficient to embrace all the known facts; it was supplemented in 1813 by Avogadro's theorem—that equal volumes of gases contain the same numbers of molecules at the same temperature and pressure. These two important theoretical developments led to the association of a definite physical meaning with the idea of molecular *composition*, but ultimately proved insufficient for the interpretation of the ever-increasing mass of chemical knowledge collected under their stimulus. A further great impetus followed the introduction by Frankland and Kekulé, in 1852 onwards, of the idea of valency and the mode of building up constitutional formulæ; the conception of molecular *constitution* thus arose as a refinement on the Daltonian notion of molecular composition. In course of time the theoretical scheme once more proved insufficient to accommodate the accumulated facts, until, in 1874, van 't Hoff and Le Bel demonstrated the all-important part which molecular *configuration* plays in the interpretation of certain classes of phenomena known to the organic Chemist.

During the early days of chemical science—those of Dalton's time and perhaps also those of Frankland and Kekulé—we can believe that chemical theory may have lacked the physical reality which it now seems to us to present; the attitude of our predecessors towards the theoretical interpretation of their observations was rather that described by Plato: 'as when men in a dark cavern judge of external objects by the shadows which they cast into the cavern.' In the writings of the most clear-sighted of our forerunners we can detect an underlying suspicion of a possibility that, at some time or other, the theory by means of which chemical observations are held together may undergo an entire reconstruction; a very few years ago Ostwald made a determined attempt to treat our science without the aid of the molecular hypothesis, and indeed suggested the desirability of giving the Daltonian atomic theory decent burial.

The last ten years or so has seen a change in this attitude. The development of Organic Chemistry has revealed so complete a correspondence between the indications of the conception of molecular constitution and configuration and the observed facts, and recent work on the existence of the molecule, largely in connection with colloids, with radioactivity, and with crystal structure, is so free from ambiguity, that persistence of doubt seems unreasonable. Probably most chemists are prepared to regard the present doctrine of chemical constitution and configuration as proven; although they may turn a dim vision towards the next great development, they have few misgivings as to the stability of the position which has already been attained.

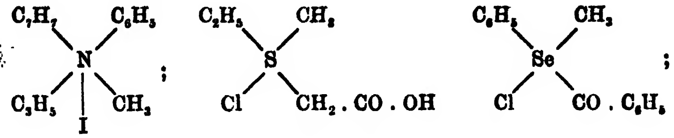
Let us consider how far the study of Organic Chemistry has hitherto led us; we may pass over the gigantic achievements of those who in past generations determined constitution and performed syntheses, thus making the subject one of the most perfect examples of scientific classification which exist, and turn

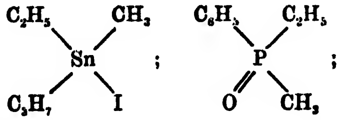
to the question of molecular configuration. In 1815 Biot observed that certain liquid organic substances deflect the plane of polarisation of a transmitted ray of light either to the right or to the left; half-a-century later Pasteur and Paternò pointed the obvious conclusion, namely, that the right- or left-handed deviation thus exerted must be due to a corresponding right- or left-handedness in the configuration of the chemical molecule. A scheme representing such right- or left-handedness, or enantiomorphism, was first enunciated by van 't Hoff and Le Bel upon the basis of the previously established doctrine of chemical constitution; briefly stated, the idea suggested was that the methane molecule, CH_4, was not to be regarded as extended in a plane in the manner represented by the Frankland-Kekulé constitutional formula, but as built up symmetrically in three-dimensional space. The carbon atom of the methane molecule thus occupies the centre of a regular tetrahedron, of which the apices are replaced by the four hydrogen atoms. A methane derivative, in which one carbon is separately attached to four different univalent atoms or radicles of the type CXYZW, should thus exist in two enantiomorphous configurations, one exhibiting right- and the other left-handedness. The inventors of this daringly mechanistic interpretation of the far less concrete constitutional formulæ were able to interpret immediately a large number of known facts, previously incomprehensible, by means of their extension of the Frankland-Kekulé view of constitution. They showed that every substance then known, which in the liquid state exhibited so-called optical activity, could be regarded as a derivative of methane in which the methane carbon atom was attached to four different univalent atoms or groups of atoms; a methane carbon atom so associated is termed an asymmetric carbon atom. It is of interest to note that the van 't Hoff-Le Bel deduction resulted from the discussion of the behaviour of organic substances of some molecular complexity; the optically active substances then known were mostly the products of animal or vegetable life, and among them none occurs which contains less than three carbon atoms in the molecule. Lactic acid, $CH_3 . CH(OH) . CO . OH$, is practically the most simple optically active substance of natural occurrence; it contains twelve atoms in the molecule, and it has only recently been found possible to associate optical activity with a much more simply constituted substance, namely, chloriodomethanesulphonic acid $CHClI . SO_3H$, the molecule of which contains less than 5 per cent. of carbon and only nine atoms, four more than the minimum number, five, which theoretically can give rise to optical activity.[1]

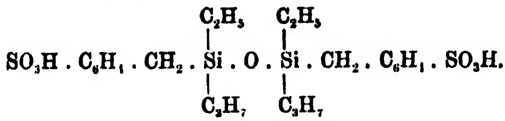
The working out of the practical consequences of the doctrine of the tetrahedral configuration of the methane carbon atom by von Baeyer, Emil Fischer, and Wislicenus is now a matter of history; the acquisition of masses of experimental data, broad in principle and minute in detail, placed the van 't Hoff-Le Bel hypothesis beyond dispute. The rapid growth of Organic Chemistry as a classified subject contrasted strongly with that of Inorganic Chemistry, in which the collection of a great variety of detailed knowledge incapable of far-reaching logical correlation formed the most striking feature; in fact, the extension of the conclusion, proven in the case of carbon compounds, that the Frankland-Kekulé constitutional formulæ must be translated into terms of three-dimensional space, to compounds of elements other than carbon, did not immediately follow the application of the theory to this element. Twenty years ago, indeed, the idea prevailed that carbon compounds differed radically from those of other elements, and we were not prepared to transfer theoretical conclusions from the organic to the inorganic side of our subject. In 1891, however, Le Bel stated that he had found optical activity associated with asymmetry of a quinquevalent nitrogen atom; although the experimental work upon which this conclusion was founded is now known to be incorrect,[2] the conception thus put forward was important, as suggesting that the notion of space-configuration could not be restricted logically to methane derivatives. When it was proved in 1899 that benzylphenylallylmethylammonium iodide could exist in a right- and left-handed configuration, it became necessary to admit that the spacial arrangement of the parts of a chemical molecule, previously restricted to methane derivatives, must be extended to ammonium salts.[3]

[1] Pope and Read, *Trans. Chem. Soc.*, 1914, **105**, 811. [2] *Ibid.*, 1912, **101**, 519.
[3] Pope and Peachey, *Trans. Chem. Soc.*, 1899, **75**, 1127.

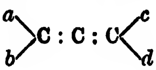
The demonstration that optical activity, or enantiomorphism, of molecular configuration is associated not only with the presence of an asymmetric quadrivalent carbon atom, but also with that of a nitrogen atom attached to five different radicles, was the result of an improvement of technique in connection with the study of optical activity; previously the resolution into optically active components of a potentially optically active basic substance had been attempted with the aid of naturally occurring optically active weak acids of the general type of *d*-tartaric acid. The application of the strong *d*- and *l*-bromocamphorsulphonic acids and the *d*- and *l*-camphorsulphonic acids to such purposes rendered possible the isolation of the optically active substances containing no asymmetric atom other than one of quinquevalent nitrogen. The resolution of asymmetric quaternary ammonium salts of the kind indicated was rapidly followed by the preparation of optically active substances in which the enantiomorphism is associated with the presence of an asymmetric sulphur, selenium, tin, phosphorus, or silicon atom; compounds of the following constitutions were thus obtained in optically active modifications :—



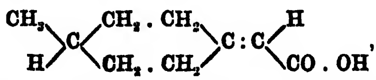




In all this work, and amongst all the varied classes of optically active compounds prepared, it was in every instance possible to indicate one particular quadrivalent or quinquevalent atom in the molecule which is separately attached to four or five different atoms or radicles; the enantiomorphism of molecular configuration may be detected, in fact, by the observation that such an asymmetric atom is present. It must, however, be insisted that the observed optical activity is the result of the enantiomorphism of the molecular configuration; the asymmetry of a particular atom is not to be regarded as the cause of the optical activity but merely as a convenient geometrical sign of molecular enantiomorphism. In 1874 van 't Hoff realised that molecular enantiomorphism and optical activity might conceivably exist without the presence of an asymmetric carbon atom, and suggested that compounds of the type



should be of this kind. Previously this particular case had escaped realisation experimentally, but an example fulfilling similar conditions was described in 1909; in this year the *d*- and *l*-isomerides of 1-methylcyclohexylidene-4-acetic acid,

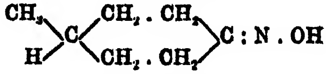


were obtained.[4] The consideration of the constitution of these substances shows

[4] Perkin, Pope, and Wallach, *Trans. Chem. Soc.*, 1909, 95, 1789; Perkin and Pope, *Trans. Chem. Soc.*, 1911, 99, 1510.

no carbon atom which is attached to four different groups, but a study of the solid model representing the molecular configuration built up in accordance with the van 't Hoff-Wislicenus conclusions reveals the enantiomorphism.

It is of some importance to note that the configurations assigned to such optically active substances as have been mentioned above, on the basis of the experimental evidence, are of as symmetrical a character as the conditions permit; the Kekulé formula for methane, CH_4, in which all five atoms lie in the same plane, is not of so highly symmetrical a character as the van 't Hoff-Le Bel configuration in which the four hydrogen atoms are situate at the apices of a regular tetrahedron described about the carbon atom as centre. Some influence seems to be operative which tends to distribute the component radicles in an unsymmetrical molecule in as symmetrical a manner as possible; recent work indicates, however, that this is not always true. During the past few years Mills and Bain [6] have shown that the synthetic substance of the constitution



can be resolved into optically active modifications. The conclusion is thus forced upon us that the trivalent nitrogen atom in such compounds is not environed in the most symmetrical manner possible by the surrounding components of the molecule; the experimental verification which the conclusions of Hantzsch and Werner, concerning the isomerism of the oximes, thus derive, constitutes the first really direct evidence justifying their acceptance.

Quite recently, and by the application largely of the optically active powerful sulphonic acids derived from camphor, Werner has made another great advance in connection with the subject of optical activity. He has obtained a number of complex compounds of chromium, cobalt, iron, and rhodium in optically active modifications.

The foregoing brief statement probably suffices to indicate the progress which has been made during the last twenty years in demonstrating that the atoms or radicles associated in the chemical molecule do not lie in one plane but are disposed about certain constituent atoms in three-dimensional space; careful study of the present stage of progress shows that we must attribute to molecular configuration, as determined by modern chemical methods, a very real significance. It can no longer be supposed to possess the purely diagrammatic character which attached to the Frankland-Kekulé constitutional formulæ; it seems to be proved that the men who developed the doctrine of valency were not merely pursuing an empirical mode of classification, capable of various modes of physical interpretation, but were devising the main scheme of a correct mechanical model of the chemical universe.

The development of a branch of science such as that now under discussion is, to a considerable extent, an artistic pursuit; it calls for the exercise of manipulative skill, of a knowledge of materials, and of originality of conception, which probably originate in intuition and empiricism, but must be applied with scientific acumen and logical judgment. For reasons of this kind many gaps occur in our present knowledge of the subject; although so many important conclusions find an unshakable foundation on facts relating to optical activity, we have as yet no clear idea as to why substances of enantiomorphous molecular configuration exhibit optical activity. Great masses of quantitative data referring to optical activity have been accumulated; something has been done towards their correlation by Armstrong, Frankland, Pickard, Lowry, and others, but we still await from the mathematical physicist a theory of optical activity comparable in quantitative completeness to the electro-magnetic theory of light. Until we get such a theory it seems unlikely that much further progress will be made in interpreting quantitative determinations of rotation constants.

That aspect of stereochemistry which has just been so briefly reviewed represents a situation which has been attained during the natural development

[6] *Trans. Chem. Soc.*, **1910, 97**, 1866.

of Organic Chemistry by methods which have now become traditional; progress has been made by the application of strictly logical methods of interpretation to masses of experimental data, and each new conclusion has been checked and verified by the accumulation of fresh contributions in the laboratory. The sureness of the methods adopted could not fail to lead to the intrusion of stereochemistry into adjacent fields of scientific activity; bio-chemistry, the study of the chemical processes occurring in living organisms, is already largely dominated by stereochemistry, and the certainty with which stereochemistry has inspired us as to the reality of the molecular constitution of matter is exerting a powerful influence in other branches of natural science. Quite possibly, however, the acquaintance which every chemist possesses of the great progress already made upon one particular set of lines is to some extent an obstacle to his appreciation of new directions in which further great stereochemical advances may be anticipated.

A little reflection will show that the study of the relation between the crystalline form and chemical constitution or configuration of substances in general may confidently be expected to lead to important extensions of our knowledge of the manner in which the atoms are arranged in molecular complexes. The earlier crystallographic work of the nineteenth century led to the conclusion that each substance affects some particular crystalline form, that the regular external crystalline shape is an expression of the internal structure of the crystal, and that a determination of the simpler properties—geometrical, optical, and the like—of a crystalline material constitutes a mode of completely characterising the substance. Later work during the last century demonstrated that the properties of crystalline substances are in entire harmony with a simple assumption as to the manner in which the units or particles of the material are arranged; *the assumption is that the arrangement is a geometrically 'homogeneous' one, namely, an arrangement in which similar units are uniformly repeated throughout the structure, corresponding points presenting everywhere a similar environment.* The assumption of homogeneity of structure imposes a definite limitation upon the kinds of arrangement which are possible in crystals; it leads to the inquiry as to how many types of homogeneous arrangement of points in space are possible, and to the identification of these types with the known classes of crystal symmetry. The final conclusion has been attained that there are 230 geometrically homogeneous modes of distributing units, or points representing material particles, throughout space; these, the so-called 230 homogeneous 'point-systems,' fall into the thirty-two types of symmetry exhibited by crystalline solids. The solution of the purely geometrical problem here involved was commenced by Frankenheim in 1830, and finally completed by Barlow in 1894; it brings us face to face with the much larger stereochemical problem—that of determining what the units are which become homogeneously arranged in the crystal, why they become so arranged, and in what way a connection can be established between chemical constitution and crystal structure.

Since the conception of homogeneity of structure alone is clearly insufficient for the interpretation of the more advanced problem, some further assumption must be made as a foundation for any really comprehensive attempt to collate the quantities of isolated facts bearing upon the subject. Of the many assumptions which have been made in this connection only one, which may now be stated, has as yet proved fruitful in the sense that it serves to correlate large numbers of known experimental facts, and that it indicates the way to the discovery of fresh facts. The assumption is that each atom in a crystalline structure acts as a centre of operation of two opposing forces: (*a*) a repellent force, attributable to the kinetic energy of the atom, and (*b*) an attractive force, both forces, like gravity, being governed by some inverse distance law. Such an assumption forms an essential part of the classical work of Clerk Maxwell and van der Waals on the kinetic theory of gases and liquids. Its application to solid crystalline substances, where it must be applied in conjunction with the principle of structural homogeneity, was made by Barlow and myself in 1906.

The operation of the assumption just stated is readily visualised by considering the simplest possible case, that, namely, of a crystalline element each

molecule of which consists of but one atom and in which all the atoms are similar. Consideration of this kind of case shows that the set of identically similar centres of attracting and opposing forces will be in equilibrium when one particular simple condition is fulfilled; the condition is that, with a given density of packing of the centres, the distance separating nearest centres is a maximum. Two homogeneous arrangements of points fulfil this condition, and these exhibit the symmetry of the cubic and the hexagonal crystalline systems.

Since the nature of the two arrangements of points is not easily realised by mere inspection, the systems must be presented in some alternative form for the purpose of more clearly demonstrating their properties; this is done conveniently by imagining each point in either arrangement to swell as a sphere until contact is made with the neighbouring points. The two arrangements then become those shown in Figs. 1 and 2, and are distinguished as the cubic and the hexagonal closest-packed assemblages of equal spheres; they differ from all other homogeneous arrangements in presenting maximum closeness of packing of the component spheres. The equilibrium condition previously remarked—that, with a given density of distribution of the force centres in space, the distance separating nearest centres is a maximum—is revealed in the assemblages of spheres as the condition that the spheres are arranged with the maximum closeness of packing.

A further step is yet necessary. Each point in the arrangements considered is regarded as the mean centre of an atom of the crystalline element, but the assumption originally made states nothing about the magnitude of the atom itself; it is therefore convenient to regard the whole of the available space as filled by the atoms, without interstices. This is conveniently done by imagining tangent planes drawn at each contact of sphere with sphere, so partitioning the available space into plane-sided polyhedra, each of which may be described as the domain of one component atom. The twelve-sided polyhedra thus derived from the cubic and the hexagonal assemblages represent the solid areas throughout which each atom exercises a predominant influence in establishing the equilibrium arrangement.

The two assemblages can now be described in a quantitative manner by stating the symmetry and also the relative dimensions of each. The cubic assemblage exhibits symmetry identical with that of the cube or the regular octahedron, a symmetry characteristic of so-called holohedral cubic crystals; the relative dimensions in different directions are defined by the symmetry. The assemblage can, in fact, be referred to three axes parallel to the edges of a cube, and as these directions are obviously similar in a cube, their ratios are of the form, $a : b : c = 1 : 1 : 1$. This expression indicates that if the assemblage, supposed indefinitely extended through space, is moved by a unit distance in either of the three rectangular directions a, b, and c, the effect, as examined from any point, is as if the assemblage had not been moved at all.

The symmetry of the hexagonal assemblage is identical with that of a hexagonal prism or of a double hexagonal pyramid, and is that characteristic of the so-called holohedral, hexagonal, crystalline system; the relative dimensions are no longer defined entirely by the symmetry, and are conveniently stated as the ratio of the diameter, a, of the prism or pyramid, to the height, c, of the pyramid. The ratio, $a : c$, for the assemblage of spheres under discussion can be calculated; it assumes two forms, corresponding to two modes of selecting alternative principal diameters of the prism as unit. The alternative ratios are:

$$a : c = 1 : 1{\cdot}6330 \text{ or } a : c = 1 : 1{\cdot}4142.$$

This somewhat lengthy theoretical discussion has now reached a stage at which it can be applied to the observed facts; the accompanying table (Table I.) states the mode in which crystalline substances of different degrees of molecular complexity distribute themselves amongst the various crystal systems. Of the elements which have been crystallographically examined, 50 per cent. are cubic, whilst a further 35 per cent. are hexagonal: and consideration of the data for these latter shows that they exhibit approximately the axial ratios characteristic of the hexagonal closest-packed assemblage; thus magnesium shows $a : c = 1 : 1{\cdot}6242$, and arsenic the ratio $a : c = 1 : 1{\cdot}$ [illegible]

System		Inorganic Substances, the Number of Atoms in the Molecule of which is respectively:					Organic Substances
		Elements					
		2	3	4	5	More than 5	
	Per cent.						
Cubic	50	68·5	42	5	12	5·8	2·5
Hexagonal	35	19·5	11	35	38	14·6	4·0
Tetragonal	5	4·5	19	5	6	7	5·0
Orthorhombic	5	3·0	23·5	50	36	27·3	34·0
Monosymmetric	5	4·5	3	5	6	37·3	47·5
Anorthic	0	0	1·5	0	2	8	7·0
Number of cases examined for each vertical column	140	67	63	20	50	673	585

Whilst the crystal structure of some 85 per cent. of the crystalline elements seems to be in general agreement with the simple assumption of equilibrium which has been made, the divergence presented by about 15 per cent. of the elements still awaits explanation. The previous discussion applies to the theoretically simple case of a monoatomic element; many of the elements are, however, certainly polyatomic. Imagine, therefore, that in the crystal structure, agreeing with the cubic or hexagonal arrangement just described, the similar atoms are grouped to form complex molecules, each containing two or more atoms; the geometrical effect of this grouping, if any, should be, first, to degrade the symmetry of the structure, and, secondly, to slightly alter its relative dimensions. It would therefore be expected that if the elements which are neither cubic nor hexagonal owe their departure from those systems to molecular aggregation, the crystal dimensions should approximate closely to those of the two ideal assemblages; this is, indeed, found to be the case. Monosymmetric sulphur, for instance, exhibits the axial ratios, $a : b : c = 0{\cdot}9958 : 1 : 0{\cdot}9988$, $\beta = 95^\circ\ 46'$; the relative dimensions in the three directions, a, b, and c, are almost the same as in the cubic system, and the angle between the directions a and c is $\beta = 95^\circ\ 46'$, instead of 90°. This substance has nearly the dimensions of a cubic crystal, and is obviously 'pseudo-cubic'; the same is true of all other elements which depart from true cubic or hexagonal symmetry.

The crystalline forms presented by the elements are consequently in accordance with the assumption that the crystal structures are equilibrium arrangements of the component atoms of the two kinds described. It is also indicated that aggregation of the atoms to form molecular complexes is responsible for the departure from simple cubic or hexagonal symmetry; in this connection it is interesting to note that the strongly coloured elements depart most widely from these two systems. Thus, the colourless modifications of carbon and phosphorus are cubic, whilst the black graphite is monosymmetric and the red phosphorus is orthorhombic in crystal form; this is in accordance with the general view that colour is the result of some particular kind of molecular aggregation.

Although so much general correspondence of a quantitative character is to be observed between the observed facts and the anticipations developed from the equilibrium assumption, it has become evident during the last year or two that the conception formed as to the nature of the equilibrium which determines the arrangement of the atoms in a crystalline element is of too simple a character. In 1912 Laue showed that on passing a narrow pencil of X-rays through a crystal plate the emergent rays were capable of forming a regular, geometrical pattern of spots upon a photographic plate placed to receive the emergent beam; the pattern of spots thus produced was in agreement with the symmetry of the direction in the crystal plate in which the beam was passed. This discovery was developed and very considerably extended by Bragg, who was able to show that an X-ray

beam undergoes reflection at the surface of a crystal plate. The interpretation of the novel results indicates that the homogeneous crystal structure acts upon the X-ray beam much as a solid diffraction grating might be expected to do, and that each deflected transmitted ray is a reflection from one set of parallel planes of atoms in the crystal.

The experimental and theoretical study of the X-ray effects has been prosecuted with brilliant success by W. H. and W. L. Bragg, the result being that a method is now available which makes it possible to determine, with very great probability, the actual arrangement of the constituent atoms in crystal structure. Sufficient time has not yet elapsed for the thorough exploitation of this new and fruitful field of research, but many data are available already for comparison with the conclusions drawn from the consideration of the equilibria possible in crystal structures; it is found that the two methods do not at once lead to identical conclusions. Thus, in accordance with the first method, the structure of the diamond would be indicated as some slight modification of the cubic closest-packed assemblage of equal spheres, the modification consisting in the main of a grouping of sets of atoms which leads to the partial cubic symmetry which the diamond apparently exhibits; one particular mode of grouping which leads to the required result consists in supposing the carbon atoms formed into sets of four, tetrahedrally arranged, two oppositely orientated sets of such tetrahedral groups being distinguished. If each of these tetrahedral groups be replaced by a single point situated at the group-centre, the structure which the Bragg experiments indicate for the diamond is obtained.

The simple geometrical relationship which thus exists between the two suggested structures for diamond raises a suspicion that the particular form in which the assumption of equilibrium is stated requires qualification: that possibly the domain of the carbon atom when packed with others, as in the diamond, does not become converted into a rhombic dodecahedron, but into a polyhedron roughly tetrahedral in shape.

Leaving this particular point for the moment and turning again to Table I., it is seen that the binary compounds, like the elements, also tend to crystallise in the cubic or hexagonal systems; the axial ratios of the hexagonal binary compounds approximate very closely to the value, $a : c = 1 : 1{\cdot}6330$, calculated for the closest-packed, hexagonal assemblage of equal spheres. The values of c/a for all the known cases are: BeO – 1·6365, ZnO – 1·6077, ZnS – 1·6350, CdS – 1·6218, and AgI – 1·6392.

Assemblages representing the crystal structures of the cubic and hexagonal binary compounds may be derived from the two closest-packed assemblages of similar spheres already described, by homogeneously replacing one half of the spheres by different ones of the same size. The degrees of symmetry presented by these arrangements are not so high as those of the unsubstituted assemblages; this is in accordance with the fact that the crystals themselves have not the full symmetry of the holohedral cubic or hexagonal system. Thus, on warming a hexagonal crystal of silver iodide, one end of the principal axis c becomes positively, and the other negatively, electrified. The axis c is thus a polar axis, having different properties at its two ends; this axis will be found to be polar in the model. Again, when hexagonal silver iodide is heated to 145°, it changes its crystalline form and becomes cubic; this so-called polymorphous change can be imitated in the hexagonal model by slightly shifting each pair of layers of spheres in the assemblage.

A very close agreement thus exists between the properties of the assemblages deduced and the observed properties of those binary compounds which crystallise in the cubic or hexagonal systems. The remaining 12 per cent. or so are not, in general, pseudo-cubic or pseudo-hexagonal, and it is noteworthy that they comprise those binary compounds in which the two component elements have not the same lowest valency; amongst them are the substances of the compositions, PbO, FeAs, HgO, AsS, and CuO.

On comparing the structures of the binary crystalline compounds indicated by the foregoing method of consideration with those deduced by the Braggs, discrepancies are again obvious; again, however, the former assemblage is converted into the latter by replacing groups of spheres by their group-centres. The relation thus rendered apparent is once more a suggestion that the type of equilibrium

conditions originally assumed is too simple. It will be seen, however, that the Bragg results furnish a proof of one part of the assumption made concerning equilibrium, namely, that each component atom operates separately; the discussion of the properties of crystals on the assumption that the crystal structure may be regarded as built up of similar mass-points, due to the mathematical physicists of the last century, therefore requires to be reopened. Thus, the Bragg structure of rock-salt is represented by dividing space into equal cubes by three sets of parallel planes and replacing the cube corners encountered along the directions of the cube edges by chlorine and sodium atoms alternately; each chlorine atom then has six sodium atoms as its nearest and equally distant neighbours. With which of the latter the one chlorine atom is associated to form a molecule of sodium chloride is not apparent from the nature of the crystal structure.

Time need not be now occupied with the further discussion of the crystalline structure of simple substances; until the discovery of the X-ray effects thus briefly described, no direct method of determining those structures was available, and, in view of the paucity of the experimental data, only the possibilities of arrangement could be considered in the light of the Barlow-Pope mode of treatment. It will, however, be useful to review some of the results which accrue from this latter method of regarding the problem of crystal structure in general.

Taking the general standpoint, which is also in accordance with the Bragg results, that each component atom of a crystalline structure has a separate spacial existence, and premising that the atomic domains are close-packed in the assemblage in accordance with some particular type of equilibrium law, it becomes obvious that crystalline structure presents a volume problem. The law arrived at after a careful investigation of the subject—the so-called law of valency volumes—states that in a crystalline structure, the component atoms occupy domains approximately proportional in volume to the numbers representing the fundamental valencies of the elements concerned; the student of the subject of molecular volumes will hardly accept this conclusion without convincing evidence of its correctness—it indicates, for instance, that in crystalline potassium sulphate, if the atomic volume of potassium is taken as unity, those of sulphur and oxygen each have the value two. Many different lines of crystallographic argument converge, however, to this law, and, if the latter is in the end found to be incorrect, it at least represents something fundamental which still awaits enunciation in a more generally acceptable form. A few illustrative instances may be quoted.

If valency be a volume property, the relation should be revealed in the compositions of chemical substances, especially those of composite character. The sum of the valencies in potassium sulphate, K_2SO_4, is 12, and in ammonium sulphate, $(NH_4)_2SO_4$, 24, just twice the number; the two substances are so closely related that they crystallise together to form 'solid solutions' (isomorphous mixtures). Similarly, in the alums, such as $K_2SO_4+Al_2(SO_4)_3+24H_2O$, the valencies are 12+36+96; the sum of the valencies of the water present, 96, is just twice that, 48, of those exhibited by the metallic sulphates. Similar curious numerical relationships occur in each of the well-defined series of double salts.

Again, if the valency volume law hold for two substances of different crystalline form, such as orthorhombic rubidium nitrate, $RbNO_3$, and rhombohedral sodium nitrate, $NaNO_3$, the metal, the nitrogen and the oxygen in each compound should have the respective atomic volumes, 1, 3, and 2. As the substances differ in density the absolute values of the atomic volumes of nitrogen and oxygen will differ in the two substances as examined at the same temperature; the ratios of the atomic volumes in either compound should, however, be as stated. Considering this conclusion in conjunction with the fact that these crystalline compounds represent symmetrically constructed assemblages, it would seem that the relative dimensions of the one crystal structure should be traceable in those of the other. Orthorhombic rubidium nitrate exhibits the axial ratios, $a:\bar{b}:c=1{\cdot}7336:1:0{\cdot}7106$; three rectangular co-ordinates, a, b, and c, being used as the directions of reference; rhombohedral sodium nitrate exhibits $a:c=1:0{\cdot}8276$, the co-ordinates being three axes, a, making angles of 120° in one plane, and a fourth axis c, perpendicular to a. On converting the axial

system of sodium nitrate into a simple set of rectangular axes similar to those used for rubidium nitrate, the value, $a : c = 1 : 0{\cdot}8276$, becomes

$$a : b : c = 1{\cdot}7320 : 1 : 0{\cdot}7151.$$

These values approximate very closely to those obtained by direct measurement of the orthorhombic rubidium salt. It seems difficult to avoid the conclusion that the two dissimilar crystalline structures are built up by the arrangement of layers or blocks of the same relative dimensions in two different ways, the molecule of sodium nitrate, $NaNO_3$, possessing practically the same relative dimensions as that of rubidium nitrate, $RbNO_3$; this, of course, is in disaccord with the classic conception of atomic volume, but agrees entirely with the valency volume law.

Another remarkable body of evidence is found in the interpretation of many morphotropic relationships between organic and inorganic substances which have been long recognised but have hitherto eluded interpretation. The description of one or two cases will make the bearing of the law of valency volumes clear in this connection.

d-Camphoric anhydride, $C_{10}H_{14}O_3$, and *d*-camphoric acid crystallised with acetone, $C_{10}H_{16}O_4$, 1/2 $(CH_3)_2CO$, both crystallise in the orthorhombic system and exhibit the axial ratios stated in the following Table II. :—

TABLE II.

	W	$a : b : c$	$x \quad y \quad z$
$C_{10}H_{14}O_3$	60	1·0011 : 1 : 1·7270	3·2654 : 3·2618 : 5·6331
$C_{10}H_{16}O_4$, 1/2 $(CH_3)_2CO$.	74	1·2386 : 1 : 1·7172	4·0435 : 3·2646 : 5·6060

The ratio c/b is approximately the same in the two cases and general similarity exists between the two crystalline substances. It will be observed that the values of a/b are very nearly in the ratio of the sums of the valencies, W, making up the two molecular complexes, namely, $60 : 74 = 100 : 123$. This and similar cases may be more conveniently discussed with the aid of the so-called equivalence parameters; these are the edge lengths, x, y, and z, of a parallelepipedon of which the volume is W, the sum of the valencies in the molecule, and of which the linear and angular dimensions express the crystallographic axial ratios. Thus, for orthorhombic substance, $xyz = W$, and $x : y : z = a : b : c$; the equivalence parameters of the two substances under discussion are given in the table, and it will be seen that whilst y and z are almost identical for the two, the z values differ considerably. This correspondence indicates clearly that in passing from camphoric anhydride to the acetone compound of the acid the mass added to the molecular complex, $H_2O + 1/2\ (CH_3)_2CO$, occupies a volume proportional to the number of valency units which it contributes to the structure.

A very remarkable relation has been long recognised between the crystalline forms of the three minerals chondrodite, $Mg_3(SiO_4)_2$, $2Mg(F,OH)$, humite, $Mg_5(SiO_4)_3$, $2Mg(F,OH)$, and clinohumite, $Mg_7(SiO_4)_4$, $2Mg(F,OH)$; the crystalline forms are referable to three rectangular directions, a, b, and c, and the ratio $a : b$ is practically the same for all three minerals. The relationship is at once elucidated by the law of valency volumes in a simple manner. In the molecules of the three substances the sums of the valencies of the constituent atoms are respectively 34, 48, and 62; it follows from the law that these numbers are proportional to the relative volumes of the several molecules. The ratios, $a : b : c$, being known, the dimensions can be calculated of solid rectangular blocks having these volumes and having edge lengths proportional to the axial ratios, $a : b : c$. The equivalence parameters, x, y, and z, thus calculated are given in Table III.; the first observation of importance to be made is that the equivalence parameters, x and y, remain practically constant throughout the series of three minerals.

It will be seen that chondrodite and humite, and humite and clinohumite, differ in molecular composition by the quantity, $Mg_2(SiO_4)$; they form a series in which the increment of composition is $Mg_2(SiO_4)$. Subtracting this increment from the composition of chondrodite, the residue, $Mg_1(SiO_4)_1$, $2Mg(F,OH)$,

is left. This is the composition of the mineral prolectite, and the increment, $Mg_2(SiO_4)$, is the composition of the mineral forsterite.

If the law of valency volumes be correct the equivalence parameters of forsterite should be the x and y of the first three minerals, and a value z which is the difference between the z values of chondrodite and humite, or of humite and clinohumite; further, prolectite should have x and y values identical with those of the other four minerals and a z value which is the difference of the z values of chondrodite and forsterite. It is thus possible to calculate the equivalence parameters of forsterite and prolectite without using data determined on these two minerals, and to compare the values so obtained with those calculated from the observed axial ratios of forsterite and prolectite. All the values referred to are given in Table III., and it will be obvious that the agreement between the calculated and the observed equivalence parameters is very close; *as this agreement could not occur without the operation of the law of valency volumes, which was deduced from entirely different data, strong confirmation of the accuracy of the law is provided.*

TABLE III.

Minerals	W	Axial Ratios $a : b : c$	Equivalent Parameters x	y	z	z/W
Chondrodite . .	34	1·08630 : 1 : 3·14472	2·3367	2·1510	6·7644	0·19895
Humite . . .	48	1·08021 : 1 : 4·40334	2·3343	2·1610	9·5155	0·19824
Clinohumite . .	62	1·08028 : 1 : 5·65883	2·3384	2·1646	12·2491	0·19756
Prolectite : observed	20	1·0803 : 1 : 1·8862	2·3130	2·1414	4·0385	0·19977
Prolectite : calculated	20	1·0818 : 1 : 1·8618	2·3365	2·1589	4·0211	0·19968
Forsterite : observed	14	0·9296 : 1 : 1·1714	2·3426	2·1778	2·7442	0·19601
Forsterite : calculated	14	0·9240 : 1 : 1·1741	2·3365	2·1589	2·7433	0·19585

The several illustrations of the operation of the law of valency volumes have been quoted in detail for the purpose of showing how difficult it is to avoid the conclusion that this deduction represents some physical reality. It may be traced in connection with quantitative data of other kinds; during the last few years it has been very successfully applied by Le Bas to the interpretation of the molecular volumes of liquid substances.

From what has been already said it will be seen that the great problem as to the relation between crystal structure and chemical constitution, of which the solution seems imminent, is a stereochemical one; assemblages must be built up in accordance with the principle of homogeneity and in some form of close-packing, in which each component atom of a chemical molecule is represented as the sole occupant of some specific solid area. The properties of these assemblages must also be in agreement with the crystallographic measurements and the X-ray photographs yielded by the substances represented.

A brief indication may be given of what has been already effected in this connection. The normal paraffin hydrocarbons of the general composition C_nH_{2n+2} consist of a chain of the composition $(CH_2)_n$, to each end of which one hydrogen atom is attached; in accordance with the principles already indicated, a close-packed assemblage of the empirical composition CH_2 can be constructed from carbon and hydrogen spheres of the respective volumes 4 and 1, of such a nature that it can be divided by planes into blocks, each made up of strings of the composition $(CH_2)_n$, or $.CH_2.CH_2 \ldots . CH_2 . CH_2.$ At each plane of cleavage of the assemblage hydrogen spheres can be inserted in appropriate numbers so that close-packing is restored when the cleavage faces are brought together again; the assemblage will then have the composition $H . (CH_2)_n . H$, and may be geometrically partitioned into units each representing one molecular complex of a normal paraffin. It is noteworthy that these units exhibit the configurations indicated by the van 't Hoff-Le Bel conception for the normal paraffins. Other assemblages can be constructed which represent in a similar manner the secondary and tertiary paraffins, and all these assemblages are of one particular geometrical type, that which corresponds to the chemical behaviour characteristic of the paraffins. In these assemblages

replacements may be effected so as to introduce new geometrical features of arrangement corresponding to the presence in the molecule of an ethylenic or an acetylenic bond, and thus other classes of hydrocarbons can be represented in accordance with the conception of close-packing; the process can be extended to the polymethylene and aromatic hydrocarbons and to their substitution derivatives, and throughout a close correspondence is observed between the numbers of isomerides possible, with their constitutions and configurations, and the experimental facts.

Many considerations indicate the fruitfulness of the mode of regarding organic substances just briefly sketched; one may be more particularly specified. An assemblage representative of benzene has been suggested which accords with the crystalline form and chemical properties of the hydrocarbon, and can be geometrically partitioned into units, each representing a single molecule. The equivalence parameters of the substance are

$$x : y : z = 3{\cdot}101 : 3{\cdot}480 : 2{\cdot}780.$$

The dimension y is twice the diameter of a carbon sphere, and that of z slightly less than the sum of the diameters of a carbon and a hydrogen sphere. Now a dimension approximating closely to the z value for benzene can be found amongst the equivalence parameters of large numbers of aromatic compounds, indicating that in these crystalline substances the benzene complexes are stacked one upon the other so as to preserve the z dimension, but that the columns so formed are pushed apart in the derivatives to an extent sufficient to admit of the entrance, in close-packing, of the substituting radicles. A few cases of this kind were quoted by Barlow and myself, and many others were discovered by Jerusalem;[6] quite recently the subject has been subjected to a very thorough quantitative examination by Armstrong, Colgate, and Rodd.[7] The exhaustive nature of the experimental work of these latter authors and the care with which their conclusions are drawn leave little room for doubt as to the accuracy of their main contention, namely, that the crystallographic method affords material from which the stereochemical configurations of aromatic substances can be deduced.

If crystallography is to be used as a tool in the service of stereochemistry in anything like the way which has been briefly sketched in this address, a number of important results should accrue. We have seen that in the structure assigned to rock-salt, each sodium atom is identically related to six chlorine atoms; only when the crystal is disintegrated by solution in water does the necessity arise for a choice to be made, the sodium atom then selecting one particular chlorine atom as a mate. Even then the sodium chloride molecule present in solution appears to spend the greater part of its time in dissociation, namely, in the act of changing its partner. There is thus in the theory of crystal structure something which bears a superficial relationship to electrolytic dissociation, and the further study of this aspect of the subject may be fruitful.

Again, the solid crystalline structures which we have attempted to build up present, as one essential feature, the property that they can be partitioned geometrically into unit cells, each composed of one molecule of the substance; thus, the rock-salt structure can be partitioned into cells each representing the molecule NaCl. In this instance, the partitioning can be performed in a variety of ways corresponding to the allocation of one particular sodium atom to either of six chlorine atoms; the alternative modes of partitioning lead to the production of molecular units of identical configuration. In many cases, however, alternative methods of geometrically partitioning the assemblage representing the crystalline structure do not yield units of the same configuration; thus, the assemblage representing phloroglucinol can be geometrically partitioned in two distinct ways. Each of these gives a unit of the composition $C_6H_6O_3$, but the configuration of the unit of the one partitioning corresponds to the chemical structure of the 1 : 3 : 5-trihydroxybenzene,

$$HC\begin{matrix}\diagup C(OH) . CH \diagdown \\ \diagdown C(OH) : CH \diagup\end{matrix}C(OH)$$

[6] *Trans. Chem. Soc.*, 1909, 95, 1275.

[7] *Trans. Chem. Soc.*, 1910, 97, 1578; *Proc. Roy. Soc.*, A, 1912, 87, 204; 1913, 89, 292; 1914, 90, 111.

whilst the other exhibits the structure of the symmetrical triketohexamethylene,

$$H_2C\begin{array}{l}\diagup CO.CH_2\diagdown \\ \diagdown CO.CH_2\diagup\end{array}CO.$$

A new suggestion is thus made to the effect that tautomerism consists in the possibility of geometrically partitioning the close-packed assemblage in two or more alternative ways, each giving molecular units of the same composition but of different constitutions. The idea that in the occurrence of tautomerism some component atom wanders from one position to another in the molecule is thus rejected; the change in constitution arises from the transference of atoms as between two or more molecules. As the older conceptions of the mechanism of tautomerism do not provide a satisfactory explanation of the experimental facts, the suggestion now made is perhaps worthy of consideration.

The new line of work has many bearings upon the subject of chemical change; thus, the assemblage which is assigned to acetylene (or methylacetylene) is convertible, by symmetrical distortion, into that representing benzene (or the 1 : 3 : 5-trimethylbenzene, mesitylene). Further, the great change in chemical behaviour which accompanies many types of chemical substitution is possibly connected with the manner in which the actual atomic volumes are affected by the replacement; on converting benzene, in which the atomic volumes of carbon and hydrogen are as 4 : 1, into bromobenzene, a considerable increase in molecular volume occurs. The atomic volumes of carbon and hydrogen still, presumably, preserve the 4 : 1 ratio, and the volume appropriated by the entering bromine atom is approximately the same as that occupied by each hydrogen atom already present; the actual atomic volumes of carbon and hydrogen must thus be supposed to have increased during the production of bromobenzene. It can hardly be supposed that this fundamental volume change, even apart from a distortion of the aromatic ring arising from slight inequality of hydrogen and bromine atomic domains in the molecule, could occur without the exhibition of considerable differences in chemical properties as between benzene and bromobenzene.

Whatever view may be taken as to the accuracy of the conclusions concerning the relation between crystal structure and chemical constitution which are briefly discussed in the present Address, no critic will be disposed to doubt that wide developments in chemical science will result from the cultivation of crystal study; it seems clear that any satisfactory theory of the solid state must be largely crystallographic in character. The chief hindrance to progress at present consists in the lack of chemists trained in modern crystallographic methods; in my own country the only school in which chemical students were trained in Crystallography, dissociated from Mineralogy, was founded by Dr. Henry E. Armstrong and Sir Henry A. Miers in 1886. After doing a vast amount of valuable educational work this school has recently been allowed to become extinct.

In a Presidential Address to the Mineralogical Society in 1888, Mr. Lazarus Fletcher remarked that 'a knowledge of the elements of Crystallography, including the mechanics of crystal measurements, ought to be made a *sine qua non* for a degree in Chemistry at every University.' Twenty-five years later we find that no European University has applied this principle, and in consequence the chemical crystallographer has the greatest difficulty in making himself intelligible to his purely chemical colleagues. May I, in concluding, express the hope that the Colonial Universities, less fettered by tradition than their older sisters, may lead in the work of placing the subject of crystal structure in its legitimate position as one of the most important branches of modern Physical Chemistry?

The following Papers were then read :—

1. *Residual Affinity and Co-ordination. By* Professor GILBERT T. MORGAN *and* HENRY WEBSTER MOSS.

The molecular structures now known as co-ordination compounds owe their stability not merely to the forces (principal valency and residual affinity)

emanating from the central atom, but also to the mutual attractions exerted on one another by the co-ordinating or associating radicals or groups. It is precisely those radicals or groups possessing considerable residual affinity which function most frequently in the formation of co-ordinated complexes. The general tendency to form hydrated and ammoniated metallic salts is to be attributed in the main to the capacity for association exhibited by water and ammonia molecules respectively.

The phenomenon of co-ordination may be compared with the formation of fog in moist air containing minute dust-particles, and it is even more closely akin to the formation of the large ions of the atmosphere by the association of small ions with uncharged invisible water-drops.

The size of the atomic volume of the central element has a threefold influence on the stability of co-ordination compounds. First, if the atomic volume is small, the residual affinity of the atom is exerted in a more concentrated form. Secondly, the co-ordinating molecules or radicals can approach nearer to the centre of the central atom when its volume is small and therefore nearer to one another so that their mutual attractions become more effective. Thirdly, as the dimensions of the co-ordinating molecules or radicals are of molecular or atomic magnitude, these segregating units will fill more completely the available space round an atom of small volume than that round an atom occupying a larger sphere. This filling up of the available space also conduces to stability, as is manifested by many stereoisomeric compounds.

The number and arrangement of the associating units have also an important bearing on the stability of the co-ordination complex. It is obvious that the most stable system will be that in which there is a symmetrical distribution of the forces interacting between the associating units, a condition which is attained by taking such a number of units that they can be arranged symmetrically over the surface of a sphere. This problem has but few solutions, inasmuch as there are only five regular solids, the tetrahedron, octahedron, cube, icosahedron, and dodecahedron, with four, six, eight, twelve, and twenty vertices respectively. These integers will be the co-ordination numbers corresponding with the theoretically possible most stable systems. Molecular aggregations exist corresponding with four of these arrangements—that is, with all possible cases except that of the dodecahedron. There are also examples of less symmetric arrangements which become stable in certain circumstances.

In addition to the centric co-ordination complexes with associating units arranged round a central atom, it is highly probable that co-ordination sometimes leads to cyclic arrangements, as, for example, in the following instances:—The basic glucinum acetate, butyrate, &c., the dichloride and dibromide of molybdenum, and the reduction products of the pentahalides of columbium and tantalum.

As an example of the application of the co-ordination theory to compounds of technical importance may be cited the case of the lakes of acidic colouring-matters developed in mordant dyeing. The simplest of these are the iron, chromium, and cobalt lakes of the *ortho*-quinoneoxime dyes, which are undoubtedly internally co-ordinated compounds.

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2. *A Device for the Representation of the Natural Classification of the Elements. By* Professor Orme Masson, *F.R.S.*

TUESDAY, AUGUST 18.

Joint Discussion with Section A on the Structure of Atoms and Molecules.—See p. 293.

WEDNESDAY, AUGUST 19.

The following Papers were read :—

1. *A New Method for the Determination of Vapour Pressures and an Examination of a Source of Error in certain Dynamical Methods. By* F. H. Campbell, *M.Sc.*

Since none of the accepted methods is suitable for the determination of the vapour pressure of a binary mixture of a volatile with a non-volatile liquid a new method has been devised for the purpose.

The principle used is that of allowing a liquid saturated with a suitable gas, usually hydrogen, to evaporate into an enclosed space filled with the same gas at the same temperature and pressure, the latter being approximately atmospheric. The extra pressure exerted by the vapour is measured by means of an open mercury manometer after the volume has been restored to its original value by means of a levelling vessel. The method can be applied to volatile organic liquids of many kinds, since they come into contact with glass and mercury only. The liquid is enclosed in a glass tube projecting through a rubber stopper, which closes an opening at the bottom of the vessel, the stopper being protected from the action of the liquid by a layer of mercury. When the apparatus has reached the temperature of the constant temperature bath in which it is immersed, the tube, previously deeply scratched, is broken by gentle sideways pressure on the projecting end. Saturation of the gas by the vapour is hastened by gently shaking the apparatus.

Experiments have been made with the following liquids and gases: Methyl alcohol, ethyl alcohol, diethyl ether, carbon disulphide, chloroform and water, evaporating into carbon dioxide, air, hydrogen, and, in the case of chloroform, nitrogen in addition. In every case the values obtained, though very concordant, are lower than the most reliable results obtained by the ordinary static method. The magnitude of the error evidently depends on the solubility of the particular gas in the particular liquid as it diminishes in each case, except that of water, in the order carbon dioxide, air, hydrogen. With water at 60° C. the results obtained with air and hydrogen are practically identical. The error when hydrogen is used is generally less than 1 per cent., and it is considered that the agreement is sufficient, as with mixtures the ratio between the observed pressure of the solution and that of the pure volatile solvent is to be considered. With air the errors are from 2 to 6 per cent., and it is concluded that methods depending on the saturation of a current of a gas passing through or over solution and pure solvent must therefore involve more or less error from this cause, a fact which does not seem to have been appreciated in the past. Perman ('Proc. Roy. Soc.' 1903, **72**, 72) and Krauskopf ('J. Phys. Chem.' 1910, **14**, 489) obtained satisfactory results with water, although those of Regnault ('Ann. Chim. Phys.' 1845 (3), **15**, 129) and Tammann ('Wied. Ann.' 1888, **23**, 322), which are lower than those obtained by the static method, are brought into satisfactory agreement with these upon the author's assumption, which indicates that the errors introduced by the presence of a dissolved gas are negligible under certain conditions.

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2. *A New Method for determining the Specific Heats of Liquids. By* Ernst Johannes Hartung, *B.Sc*

The method described, which was suggested by Professor Orme Masson, is a modification of the mixture method for determining specific heats. The principle consists in measuring the lowering in temperature of a known amount of the particular liquid on the introduction of a definite weight of dry ice contained in a thin glass bulb. The calorimeter is a thin glass vessel of about one hundred cubic centimètres capacity, and is supported inside a silvered Dewar tube. A well-fitting rubber stopper closes the mouth of this tube, making the apparatus airtight. Through the stopper is fitted a Beckmann thermometer and also a thin glass stirring rod, the lower end of which is suitably shaped to receive the small ice-bulb. A third hole, lined with glass and closed with a

well-fitting glass stopper, passes through the rubber stopper and serves for the introduction of the ice-bulb. This last consists of a small sealed thin glass cylindrical bulb, containing a definite weight of distilled water and also as much silver gauze as possible. The last ensures rapid heat conduction, and makes the bulb heavy enough to sink in dense liquids. The bulb is suspended by a fine platinum wire.

The liquid to be experimented with is introduced into the calorimeter by means of a standardisation pipette, and the apparatus is closed until constant temperature is attained. The ice-bulb has meanwhile been frozen in a mercury bath supported in an ordinary freezing-point apparatus. When the temperature of the mercury is constant at from -3° to -4°, the bulb is removed by its suspension and rapidly introduced into the lower part of the stirring rod in the calorimeter. The liquid is then stirred by hand until constant temperature is again attained, which usually requires about three minutes. Radiation corrections are then applied and the specific heat of the liquid calculated, the heat capacity of the ice-bulb being accurately known. The experiments should be performed in a room regulated to constant temperature.

The advantages claimed for the method are its simplicity, its rapidity, and its accuracy. Experiments with water at 25° C. gave consistent results agreeing to within 0·4 per cent. When ether was used, it was found necessary to coat the rubber stopper with tinfoil in order to protect it. The results with ether at 25° C. agreed to within 1·4 per cent. (the vapour pressure of ether at this temperature is 545 mm.). The specific heats of several sulphuric-acid-water mixtures were also measured and compared with the classical results of J. Thomsen. The average divergence was less than one per cent. Further measurements with different liquids are now in progress.

The apparatus described is not suitable for a viscous liquid (such as glycerine) owing to inefficient stirring. By having another liquid than water in the carrier-bulb, the scope of the method can probably be extended.

8. *The Influence of Weather Conditions upon the Amounts of Nitric Acid and of Nitrous Acid in the Rainfall near Melbourne, Australia.* By V. G. Anderson.

Daily determinations of the amounts of nitric acid and of nitrous acid in the rainfall at Canterbury, near Melbourne, have been made since November 1, 1912. The results to February 28, 1914, when correlated with meteorological data for Melbourne and daily isobaric charts of Australia, reveal the existence of a relation between weather conditions and the amounts of nitrogen acids in rain-water.

The concentration of nitric acid reached a maximum in summer, a minimum in winter, and an intermediate position during autumn and spring. The concentration of nitrous acid reached a maximum in winter, and a minimum in summer. The ratio of nitric nitrogen to nitrous nitrogen was highest in summer and lowest in winter. On many occasions during winter the ratio was approximately as 1 : 1. A relation between atmospheric temperature and this ratio was noted. Its nature was shown by plotting the mean minimum temperature of each month with the mean monthly ratios, the curve being of the same type as those which express changes of chemical velocity with temperature. The ratio is doubled for equal increments of temperature. From the results it would appear that in rain-water nitric and nitrous acids are formed in equal molecular proportions, and that, if the ratio could be determined instantly, or before any change could ensue, it would invariably be as 1 : 1. In cold weather the velocity is retarded to such an extent that little change occurs even after comparatively long periods; hence the increased amounts of nitrous acid found in winter. In hot weather, the velocity being greatly increased, the residual amounts of nitrous acid are very small, nearly all having been converted into nitric acid. The facts point to atmospheric nitrogen peroxide as the source of nitric and nitrous acids in rain-water, as this gas reacts with water, forming these acids in equal molecular proportions.

In a graph plotted with daily concentrations of total (nitric plus nitrous) nitrogen as abscissæ, and with rainfall as ordinates, the points are found to arrange themselves into a series of rectangular hyperbolæ. Further, each group of points lying along a particular curve is found to correspond with falls of rain occurring during one particular type of weather. From this it follows that for a particular type of weather (1) the concentration of oxidised nitrogen varies inversely as the rainfall; (2) the product of the concentration and the rainfall is constant; (3) the total weight per unit area of oxidised nitrogen precipitated with rain falling during twenty-four hours is constant. In brief, the amount of oxidised nitrogen per acre carried down by rain falling on any day is a function of the type of weather, and, within certain limits, is independent of the amount of rainfall. These facts may be explained by assuming that for each type of weather there exists in the air a definite concentration of nitrogen peroxide, and that this soluble gas is completely washed out of the air by the first portions of a shower: any further rain falling through the now purified air not increasing the amount of oxidised nitrogen in the rain-water, but, by dilution, decreasing the concentration.

Nine well-defined recurring types of weather have been investigated. These may be classified into three groups, as follows: (1) Antarctic types; (2) Tropical types; (3) Divided control (Antarctic and Tropical) types. The accompanying table shows the number of examples of each type investigated, together with the oxidised nitrogen constant in pounds per thousand acres, for each type.

		Number Examined	Oxidised Nitrogen Constant. Pounds per 1,000 acres
Antarctic Types—			
Λ-shaped Antarctic depressions	(*a*) rear	35	1·5
	(*b*) crest	28	2·5
	(*c*) front	10	4·1
Tropical Types—			
Tropical (or monsoonal) depressions	(*g*) spring and autumn type	6	16·0
	(*h*) summer type	3	24·0
	(*i*) 'heat-wave' type	2	35·0
Divided Control Types—			
(*d*) Antarctic depressions with *slight* Tropical influence		6	6·1
(*e*) Antarctic depressions with *strong* Tropical influence		4	8·5
(*f*) Tropical depressions with *slight* Antarctic influence		5	12·0

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4. *A Comparison of the Phenomena of the Occlusion of Hydrogen by Palladium and by Charcoal. By* Dr. A. Holt.

When all the known facts concerning the occlusion of hydrogen by palladium and by charcoal are examined and compared, it appears that, in the case of charcoal, absorption and surface condensation, without chemical action, occurs, but with palladium the evidence is in favour of the formation of a compound in addition to surface condensation. In both cases there is evidence that allotropes of the occluding solids exist, one allotrope occluding gas with far greater avidity than the other.

SYDNEY.

FRIDAY, AUGUST 21.

The following Papers were read :—

1. *Non-Aromatic Diazonium Salts. By* Professor GILBERT T. MORGAN *and* JOSEPH REILLY.

The diazotisability of an organic primary amine is in all probability connected with the presence in the basic molecule of an unsaturated group, for it has not yet been found possible to diazotise the salt of any primary base having its amino-group attached directly either to a fully saturated radical or to a completely hydrogenised ring.

It is, however, not essential that the unsaturated radical should be aromatic or homocyclic in character, and certain non-aromatic amines are known to possess in varying degrees the property of diazotisability. This property has been demonstrated in the case of the following heterocyclic bases not merely by detecting the presence of diazo-compounds in solution, but also by the isolation of the diazonium salts.

4-Amino-1-phenyl-2 : 3-dimethylpyrazolone (4-amino-antipyrine) when diazotised with ethyl nitrite in hydrochloric acid furnishes a well-defined crystallisable *diazonium* hydrochloride $(C_{11}H_{11}ON_4Cl)_2HCl$ from which the crystalline dichromate $(C_{11}H_{11}ON_4)_2Cr_2O_7$; aurichloride $(C_{11}H_{11}ON_4)AuCl_4$ and platinichloride $(C_{11}H_{11}ON_4)_2PtCl_6$ of normal composition have been prepared.

4-Amino-3 : 5-dimethylpyrazole, a base containing no aromatic substituent whatever, gave rise to a remarkably stable colourless diazonium chloride, crystallising with great facility, and permanent under ordinary atmospheric conditions. Although the parent base forms a dihydrochloride, $C_5H_9N_3$. 2HCl, one of the salt-forming centres disappears in diazotisation, the diazonium chloride $C_5H_7N_4Cl$ corresponding in composition with the salt of a monacidic base.

The replacement of the diazonium group by a triazo-radical restores this suppressed salt-forming centre, the product, 4-triazo-3 : 5-dimethyl-pyrazole being a basic compound which has the remarkable property of developing characteristic colorations with phenols in alkaline solutions.

Aminomethyltriazole can be diazotised in nitric acid solution without loss of diazo-nitrogen, although in hydrochloric acid effervescence is copious even at 0° C.

The diazotisability of wool is usually attributed to the presence in this material of aromatic amino- groups; but in view of the foregoing results it appears possible that the interaction of wool and nitrous acid may be due in part to the presence of heterocyclic rings comparable with those of the pyrazole, triazole, or thiazole series.

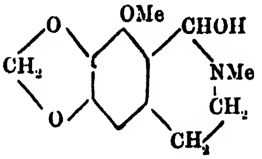
2. *The Synthesis of Isoquinoline Alkaloids. By* Professor R. ROBINSON.

Many pseudo- bases of isoquinoline type—for example, cotarnine, hydrastinine, berberine, isoquinoline methyl hydroxide—readily undergo condensations with the most varied classes of organic substances, and the greater number of these reactions can be generalised in the scheme :—

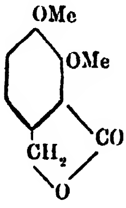
$$\diagup CHOH-NMe- + HR \rightarrow -\overset{\displaystyle R}{\overset{|}{C}}H-NMe- + H_2O$$

The interest of these condensations is very much enhanced by the fact that they yield substances closely allied in constitution to the naturally occurring isoquinoline alkaloids, and for instance cotarnine (I) with meconine (II) gave a small yield of α-gnoscopine (III) resolvable by means of *d*-bromocamphorsulphonic acid into *d*-narcotine and *l*-narcotine, the latter proving identical with the natural base occurring in opium. Cotarnine and nitromeconine react with great facility and give rise to a nitro- base from which by elimination of the

nitro- group a stereoisomeric β-gnoscopine is obtained, and this is convertible to α-gnoscopine by prolonged heating with aqueous alcohol. By similar methods a stereoisomeride of hydrastine has been synthesised. These condensations also open up a method of synthesis of phenanthrene alkaloids (morphine group), and



(I)



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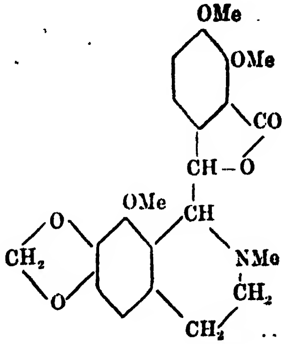


(III)

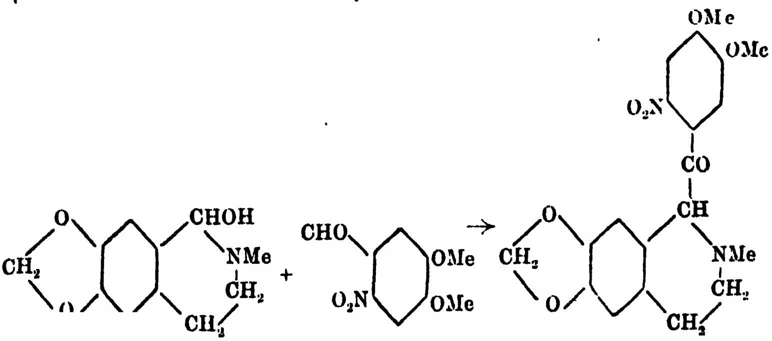
it is along these lines that further work is being prosecuted. Up to the present an isomeride of apomorphine dimethyl ether is the only example of the application of the process. It is probable that the mechanism of the pseudo- base condensation involves the stages

$$\diagup\mathrm{CHOH}-\underset{\mathrm{Me}}{\mathrm{N}}- \rightarrow -\mathrm{CH}=\overset{\mathrm{OH}}{\underset{\mathrm{Me}}{\overset{|}{\mathrm{N}}}}- + \mathrm{HR} \rightarrow -\mathrm{CH}=\overset{\mathrm{R}}{\underset{\mathrm{Me}}{\mathrm{N}}}- \rightarrow -\overset{\mathrm{R}}{\overset{|}{\mathrm{C}}}\mathrm{H}-\mathrm{NMe}-$$

a view which receives support from the remarkable rapidity of the reactions and from the observation that they occur with greatest readiness in ionising solvents. It is also considered extremely probable that such condensations have an important *rôle* in the synthesis of alkaloids in plants.

3. *The Condensation of Cotarnine and Hydrastinine with Aromatic Aldehydes.* By Mrs. G. M. Robinson, *M.Sc.*

The condensation of hydrastinine with *o*-nitrobenzaldehydes takes place in accordance with the following scheme, which represents the condensation of hydrastinine with nitroveratraldehyde : –



It is hoped that this substance will form a suitable starting-point for a synthesis of dicentrine. On reduction by stannous chloride these bases yield amino ketones, which can then be further reduced to fully saturated bases by means of amalgamated zinc and hydrochloric acid. Several bases similar to the above have been prepared.

4. *The Influence of Substituents on the Velocity of Saponification of Phenyl Benzoate.* By Dr. H. McCombie.

5. *The Colouring Matters of certain Marine Organisms.* By Dr. A. Holt.

The colouring matters of *Diazona viridis* and *Syntethys Hebridicus* have been shown to be due to a green body very similar to chlorophyl, and a purple substance which appears to be a dibromindigo. This purple compound is only found on the surface of the Ascidian Colony, and it is concluded that it acts as an oxygen carrier, since when the organism is alive and healthy it is not produced. Under these conditions it would be maintained as the colourless leuco body, but with the death of the colony changes in metabolism take place and oxidation produces the colour. The green pigment is very possibly due to a symbiotic alga. These pigments have been compared with those obtained from different species of *Murex* and from *Bonellia.*

6. *The Corrosion of Iron and Steel by Artesian Waters in New South Wales.* By Professor Fawsitt.

7. *The Use of Waste Gases of Combustion for Fire Extinctive and Fumigating Purposes.* By Dr. G. Harker.

The experiments of Clowes and Feilman on the extinctive properties of flames have shown that the flames of ordinary substances are extinguished when the oxygen in the atmosphere is reduced to about 15 per cent. The extinction of solid material, as for example ignited coal, requires a lower percentage of oxygen, and takes time owing to the need for a cooling effect. Flue gas from ordinary boilers burning coal or coke does not generally contain more than 9 or 10 per cent. of oxygen, and if pumped into a space so as to displace the air will render the atmosphere fire extinctive and will also be destructive to rats and other vermin. For practical purposes the flue gas must be cleaned and cooled before use, and formaldehyde vapours are sometimes added to it. Several installations making use of this process are now in operation.

8. *The Extraction of Radium from Australian Ores.* By S. Radcliff.

(1) A short account was given of all known occurrences of radioactive minerals in Australia.

(2) The methods now in use at the Sydney works of the Radium Hill Co. for the extraction of radium from the complex ore found at Olary, near Broken Hill, were described.

(3) The results of an examination of the various radioactive precipitates separated in the course of the works operations were given, together with the methods employed in working up preparations of ionium and actinium.

9. *The Inversion of Cane-sugar by Acids in Water-alcohol Solutions.* By George J. Burrows, *B.Sc.*

The rates of inversion of cane-sugar by hydrochloric acid and sulphuric acid have been determined in water-alcohol solutions up to 75 per cent. alcohol. In both cases a minimum velocity has been found for a solution containing about 50 per cent. alcohol by volume. From the results obtained it is evident that the velocity of inversion is not proportional to the concentration of hydrogen ions in such a series of solvents. The similarity between the curve representing the variation of the inversion velocity with the composition of the solvent and the viscosity curve for these mixtures led the author to conclude that the rate of catalysis by acids is a function of the fluidity of the medium.

The results for the inversion velocity show that the latter is not directly

proportional to the fluidity of the solvent. It was assumed that the effect of fluidity on catalysis is similar to its effect on ionic mobility as determined by electrical conductivity. Hence by dividing the inversion velocity by the conductivity of the acid in the particular solvent the result obtained expresses the activity of the catalytic ion in this medium. In this way it was found that the activity was far greater in 70 per cent. alcohol than in water.

It was therefore concluded that catalytic hydrolysis is retarded by the addition of water in the same way as esterification and other similar catalytic reactions.

MONDAY, AUGUST 24.

The following Papers were read:—

1. *On Explosions in Gases (with Demonstration).* *By* Professor H. B. Dixon, *F.R.S.*

2. *Chemical Crystallography (with Demonstration).* *By* Professor W. J. Pope, *F.R.S.*

TUESDAY, AUGUST 25.

Joint Discussion with Section M (Agriculture) on Metabolism.— See p. 663.

The following Paper, opening a Discussion on Cyanogenesis in Plants, was then read:—

The Cyanogenetic Plants of New South Wales. *By* James M. Petrie, *D.Sc.*

Of the plants growing in New South Wales, over a thousand species have been examined for hydrocyanic acid and cyanogenetic glucosides. Sixty of these gave positive results with sodium picrate paper. These include forty-four species native to New South Wales in seventeen Natural Orders.

Some plants, well known to be cyanophoric in Europe, when grown in this State have never given any reaction, although tested in all seasons.

Only a few were found to evolve free hydrocyanic acid, naturally, but all showed the presence of a glucoside and enzyme.

When the natural enzymes in these plants were killed by boiling water, the reaction to sodium picrate paper ceased; if then a few drops of emulsin, prepared from sweet almonds, were added, positive reactions were again obtained, showing that in all cases the glucosides present in the plants were capable of being hydrolysed by emulsin.

Of the sixty species stated, twenty are grasses, and these include eleven species indigenous to this State. The *Sorghum vulgare* examined by Dunstan and Henry was found to lose its glucoside when fourteen inches high, while the Australian-grown plant retains it when four feet high, and mature. Both glucoside and enzyme slowly disappear with air-drying.

One hundred and fifty species of grasses were tested systematically for seasonal variations, and some were found to give negative results at particular seasons. Two species of grasses alone evolved free hydrocyanic acid, and only one of these is available for grazing. This is the only one, except the sorghums, which has been associated with fatalities among stock.

Among the non-cyanogenetic grasses, thirty-three species contained emulsin-like enzymes.

Section C.—GEOLOGY.

President of the Section: Professor Sir T. H. Holland, K.C.I.E., F.R.S.

The President delivered the following Address at Sydney, on Friday, August 21:—

Exactly eighty-three years from the day of our arrival at Sydney, Edward Suess was born in London. Thus the day, as much as the circumstances of our meeting so far from home, serves to remind us of one who was great enough to recognise the fact that geological evidence from any part of the world has the same value as that obtained in the little continent which has been the most prolific in the products of nomenclature and the most productive in text-books.

Since the days of Charles Lyell no geologist has been so conspicuously successful in analysing the accumulated mass of evidence, in bringing together the essential facts from all lands, and in compensating for the local excesses of literature. Only those of us who, by long absence from Europe, have felt the full disadvantages of having to express our thoughts in alien terminology can appreciate the real value of Suess's great work. His death since our last meeting makes a conspicuous mark in the history of geological science.

A meeting of the British Association in Australia brings home forcibly to the members of Section C the fact that British Imperial geology is really 'the science of the Earth'; partly for this reason one feels inclined to get outside the science and take a survey of some of its suburbs. Not many of them have been left untraversed by my distinguished predecessors in this chair; but there has been of recent years a tendency to avoid the inner Earth, which has rightly been described as 'the inalienable playground of the imagination,' and consequently, therefore, common land to the geologist as well as the geodesist, physicist, and mathematician.

The geologist who looks below the purely superficial phenomena of the crust is generally regarded as straying beyond his province; but the desire to see the birth-certificate of some of the strange and often unacceptable 'causes' which the mathematical physicist offers us is a pardonable form of curiosity. Our ideas regarding intra-telluric conditions are even proving to be of economic value, one of the most recent and unexpected results of the kind being that just established by Baron von Eötvös in Hungary,[1] whose predictions now bid fair to outstrip those of the 'diviner'! Having noticed the low gravity values over the great cores of rock-salt in the Transylvanian 'Schlier,' he finds similar defects of gravity in the same region over certain of the Sarmatian and Pontian domes, which probably owe their shape to subterranean salt-plugs and are now found to be great storehouses of natural gas, which, with or without liquid petroleum, is commonly found with the saline 'Mediterranean' facies of the Upper Tertiary in Eastern Europe. Baron von Eötvös also finds that on the eastern margin of the Great Hungarian Plain, where the younger Tertiary beds are completely concealed by a mantle of alluvium, mud-volcanoes and gas-springs are sometimes found in areas of marked gravity defect, and some of these are now also being drilled for natural gas.

[1] Comptes Rendus, *XVIIème Conf. de l'Assoc. Géodés. Internat.*, Hamburg, 1912, pp. 427, 437.

When our ideas of the state of affairs below the surface thus begin to yield economic results, there is hope that they are at last steadying down, becoming more settled, and indeed more 'scientific.' It may not be unprofitable, therefore, to review some of the advances recently made in developing theoretical conceptions regarding the interior of the Earth that are of direct importance to geologists. In undertaking this review I am conscious of the fact that I shall be traversing ground that is generally familiar to all, and much of it the special property of specialists whose views I hesitate to summarise and should not dare to criticise. As the author of the 'Ingoldsby Legends' said of the only story that Mrs. Peters would allow her husband to finish, 'The subject, I fear me, is not over new, but will remind my friends—

"Of something better they have seen before." '

The intensity and quantity of polemical literature on scientific problems frequently varies inversely as the number of direct observations on which the discussions are based: the number and variety of theories concerning a subject thus often form a coefficient of our ignorance. Beyond the superficial observations, direct and indirect, made by geologists, not extending below about one two-hundredth of the Earth's radius, we have to trust to the deductions of mathematicians for our ideas regarding the interior of the Earth; and they have provided us successively with every permutation and combination possible of the three physical states of matter—solid, liquid, and gaseous.

Starting, say, two centuries back with the astronomer Halley, geologists were presented with a globe whose shell rotated at a rate different from that of its core. In more recent times this idea has been revived by Sir F. J. Evans (1878) to account for the secular variations in the declination of the magnetic needle.

Clairault's celebrated theorem (1743), on which Laplace based the most long-lived among many cosmogonies, gave us a globe of molten matter surrounded by a solid crust. Hopkins demanded a globe solid to the core, and, though his arguments were considered to be unsound, his conclusions have been revived on other grounds; while the high rigidity of the Earth as a body has been maintained by Lord Kelvin, Sir George Darwin, Professor Newcombe, Dr. Rudski, and especially by the recent observations of Dr. O. Hecker, supplemented by the mathematical reasoning of Professor A. E. H. Love. Hennessy (1886), however, concluded that the astronomical demands could be satisfied by the old-fashioned molten Earth in which the heavier substances conformed to the equatorial belt.

As long ago as 1858 Herbert Spencer suggested that, on account of its temperature being probably above the critical temperature of known elements, the centre of the Earth is possibly gaseous. Late in the 'seventies Dr. Ritter revived the idea of a gaseous core surrounded by a solid crust, and this was modified in 1900 by the Swedish philosopher, Svante Arrhenius, whose globe with a solid crust, liquid substratum, and gaseous core is now a favourite among some geologists.

Wiechert (1897) supposed that the core of the Earth, some 5,000 kilomètres in radius, is composed mostly of iron with a density of 7·8, while this is surrounded by a shell of lithoidal material having a density of about 3·0 to 3·4; and this great contrast in density is about that which distinguishes the iron meteorites generally from those of the stony class. Arrhenius also assumes that iron forms the main part of the central three-quarters, and he shows that this distribution of substance may still be consistent with his theory of a gaseous core; indeed, he not only imagines that the whole of the iron nucleus is gaseous, but also most of the siliceous shell, for he leaves only 5 per cent. of the radius as the depth of the solid and liquid shells combined.

But the variety of ideas does not end with theories on the present constitution of the globe. Poisson required the process of solidification to begin from the centre and to progress outwards, while other mathematicians had been happy with the Leibnitzian *consistentior status* as the first external slaggy crust. Since the days of Laplace all naturalists have been forced to accept the idea of a solar system formed by the cooling and condensation of a spheroidal gaseous nebula; and all except those geologists who have vainly searched for traces of the primeval crust have been happy in this belief.

Recently, however, Dr. F. R. Moulton and Professor T. C. Chamberlin

in America have brought together arguments from different points of view to construct the solar system by the aggregation of innumerable small bodies, 'planetesimals,' which have gathered into knots to form the planets. Thus, the Earth is supposed to have grown gradually by the accretion of meteoritic matter, and even now, although the process has nearly ceased, it receives much meteoritic material from outside.

With the Chamberlin-Moulton theory there must have been a time when the gravity of the Earth was insufficient to hold an atmosphere of any but the heavier gases, such as carbon dioxide; later, the Earth became heavy enough to retain oxygen, then nitrogen, water-vapour, and helium; while even now it may not be sufficiently attractive to prevent the light and agile molecule of hydrogen from flying off into space. With the growth of the young globe, the compression towards the centre produced heat enough to melt the accumulated fragments of meteoritic matter, and the molten material thus formed welled out at the surface. Such volcanic action is supposed to have predominated at the surface until an appreciable atmosphere was formed, and became charged with water, when the now familiar processes of weathering, erosion, and deposition produced the film of 'rust' which geologists know as sedimentary rocks.

With this last addition to the variegated array of theories about the physical condition of the Earth and about its genealogy, the scientific world began again to settle down into serenity, comforted by the happy feeling that all at any rate agree in regarding the Earth as a gradually cooling body, with many millions of years still before it. Then came the discovery of radium, and, with it at first, an assurance that geologists were justified in claiming a long past, to be followed by a longer future than the most optimistic philosopher had dared before to assume with our apparently limited store of Earth-heat. Now, however, Professor Joly warns us that if the deeper parts of the globe contain anything near the proportion of radioactive bodies found by him in the superficial rocks, we may even be tending in the other direction; that, instead of a peaceful cooling, our descendants may have to face a catastrophic heating; the now inconspicuous little body known as the Earth may indeed yet become famous through the Universe as a new star.[2]

To add to the variety of ideas regarding the present state of the Earth's interior, Professor Schwarz, of Grahamstown,[3] concludes that our volcanic phenomena can be accounted for on the assumption that the main mass of the Earth below a superficial layer is cold and solid throughout, being composed, like the meteorites, largely of unaltered ferromagnesian silicates and iron.

Thus, we see, whole fleets of hypotheses have been launched on this sea of controversy: some of the craft have been decoyed by the cipher-signals of the mathematician; some have foundered after bombardment by the heavy missiles classically reserved for use by militant geologists; others, though built in the dockyard of physicists, have suffered from the spontaneous combustion set up by an inadvertent shipment of radium. Still, some of these hypotheses are yet apparently seaworthy, and it may not be unprofitable to compare them with recently acquired data.

The nearest approach to actual observation with regard to the state of the Earth's interior has been obtained by the seismograph, designed to record the movements of seismic waves at great distances from the disturbing earthquake. Some of the waves sent forth from an earthquake-centre travel through the Earth, and some travel around by the superficial crust, the former reaching the distant seismograph before the latter. The seismograph, by its record of the waves that travel *through* the Earth, has thus given a certain amount of information regarding the state of the Earth's interior which R. D. Oldham aptly regards as analogous to that given by the spectroscope[4] with regard to the inaccessible atmosphere of the Sun.

[2] J. Joly, *Radioactivity and Geology*, 1909, pp. 168-172.

[3] E. H. L. Schwarz, *Causal Geology*, 1910.

[4] In his Presidential Address to the Geological Society of London in 1909, Professor W. J. Sollas (*Proc. Geol. Soc.*, 1909, p. lxxxvii) credits H. Benndorf (*Mitth. Geol. Gesellsch.* Wien, I., 1908, 336) with this pretty analogy, but Oldham has the precedence by just two years (*cf. Quart. Journ. Geol. Soc.*, vol. 62, 1906, p. 456).

The existence of two groups of earthquake-waves—those passing through, and those passing near the surface around the Earth—has long been recognised; but R. D. Oldham[5] has shown that the waves passing through the Earth are of two kinds, travelling at two different speeds.

The record on the distant seismograph thus shows three well-marked phases: the first phase, due to waves of compression passing through the Earth's interior; the second phase, due to waves of distortion,[6] also passing through the Earth's interior; and the third phase, recorded by the waves which pass around the arc along the superficial crust.

The third phase is always recorded at a time after the occurrence of the shock proportional to the arcual distance of the recording seismograph from the earthquake centre, the records of several large earthquakes showing an average speed for the waves of about three kilomètres per second. The rates of propagation of the waves giving the first and second phases are both much greater than of those forming the third phase; and up to an arcual distance of about 120° from the earthquake's centre the rate of their propagation increases with the distance. It is thus assumed that the waves giving rise to the first and second phases in each distant seismographic record, by following approximately along the chord of the arc between the place of origin and the instrument, pass through deeper layers of the Earth when the seismograph is farther away, the material at greater depths being presumably more elastic as well as denser.

But Oldham[7] has shown that when the seismograph is as much as 150° from the earthquake centre there is a remarkable decrease in the mean apparent rate of propagation of the waves giving the second phase in the record, from over six to about four and a half kilomètres per second. There is also a drop, although not nearly so marked, in the apparent speed of the waves of the first phase when transmitted to a seismograph 150° or more distant from the earthquake origin. Oldham concludes that this decrease of apparent rate for waves travelling through the Earth to places much more than 120° distant is due to their passing into a central core, four-tenths of the radius in thickness, composed of matter which transmits the waves at a markedly slow speed. Thus the earthquake waves which emerge at a distance not greater than 120° from their origin do not enter this central core, while those which pass into the Earth to a greater depth than six-tenths of the radius are supposed to be refracted on entering, and again on leaving the postulated core, in which the rate of transmission of an elastic wave of distortion is very much slower than in the main mass of the Earth around. In consequence of the refraction of these waves on passing through the central core, places situated at about 140° from an earthquake origin should be in partial shadow, due to the great dispersion of the distortional waves, and the few records made so far by seismographs thus situated with regard to great earthquakes show that there is either no, or at most a doubtful, record for the second phase, which is known to be due to the so-called distortional waves.

Oldham's deductions are based confessedly on a small number of earthquake records—he considered fourteen examples only—but the conclusions based on a small number of trustworthy records, from which variations due to the different methods of marking the phases are eliminated, are more reliable than those for which there are imperfect distant records as well as doubts regarding the exact times of the disturbances. If these observations, however, be confirmed by further records, we are justified in assuming that below the heterogeneous crust there is a thick shell of elastic material, fairly homogeneous to about six-tenths of the radius, surrounding a central core, four-tenths in thickness, which possesses physical properties utterly unlike those of the outer layers; for in this core the 'distortional' waves are either damped completely or are transmitted at very much lower speeds than in the shell.

[5] *Phil. Trans.*, Ser. A., vol. cxciv. (1900), pp. 135-74.

[6] There is more complete agreement regarding the fact that two distinct sets of waves give rise to the so-called preliminary tremors indicated by a seismographic record than about the nature of the waves. *Confer.* R. D. Oldham, *Phil. Trans.*, *loc. cit.*, and O. Fisher, *Proc. Cambr. Phil. Soc.*, vol. xii. pp. 354-361.

[7] *Quart. Journ. Geol. Soc.*, vol. 62, pp. 456-475 (1906).

One cannot consider this interesting inference from the seismographic data without being reminded of the contention of Ritter, Arrhenius, and Wilde *regarding the possibility* of a persistent gaseous core still above the critical temperature of the substances of which it is composed. According to Ritter,[8] the gaseous core is surrounded by a solid shell. Dr. Wilde[9] postulates the existence of a liquid substratum and a gaseous core within a solid crust, the two outer shells having a thickness that is 'not very considerable.' Arrhenius assumes from purely physical considerations that the solid crust is only about twenty-five miles thick, that below this it is possibly in a molten condition for about a hundred and fifty miles, and that the rest is a gas largely composed of iron under a pressure so great that its compressibility is not much less than that of steel.

The whole of these conclusions, being based on assumptions regarding the physical properties of matter under conditions of temperature and pressure that are well beyond those of actual experience, must be put on a plane of science well below that occupied by the investigations initiated by Oldham, who opens up a line of research in which, as said before, the seismograph may justifiably be compared with the spectroscope as an instrument for observing some inaccessible regions of Nature.

The mathematician apparently finds it just as easy to prove that the Earth is solid throughout as to show by extrapolation from known physical values that it must be largely gaseous. As Huxley said in his Presidential Address to the Geological Society in 1869, the mathematical mill is a mill which grinds you stuff of any degree of fineness, but, nevertheless, it can grind only what is put into it; and the seismograph thus offers a new source of substantial grist. Now that it is fairly certain that some of the earthquake-waves pass through the deeper parts of the Earth, it is obvious that a fruitful development of science will follow successful efforts to introduce precision in recording, and uniformity of expression in reading, seismographic records.

Oldham[10] has pointed out another way in which analysis of seismographic records may lead to information regarding intra-telluric conditions by comparing the records of waves that pass under the oceanic depressions with those that are sub-continental for the whole or most of their paths. By comparing the records in Europe of the Colombian earthquake of January 31, 1906, with those of the San Francisco quake in the following April, there was a greater interval noticed between the first and second phases of the Californian earthquake - an interval greater than can be accounted for by mere difference of distance between the origin of the shock and the recording instruments. The seismic waves which passed from Colombia to Europe must have travelled under the broadest and deepest part of the North Atlantic basin, while those from California ran under the continent of North America, crossed the North Atlantic not far south of Iceland, and approached Europe from the north-west, the wave paths throughout being under continents or the continental shelf of the North Atlantic. There is thus suggested some difference between the elastic conditions of the sub-oceanic and the sub-continental parts of the crust - a difference which, judging by the particular instances discussed, may extend to a depth of one-quarter of the radius, but is not noticeable in the waves which penetrate to one-third of the radius below the surface.

Obviously these data must be multiplied many times before they can be regarded as a reliable index to a natural law; but it is significant that this

[8] A. Ritter, 'Untersuchungen über die Hohe der Atmosphäre und die Constitution gasformiger Weltkörper,' Wiedemann's *Ann. d. Phys. und Chem.*, vol. v. 405, 543 (1878); vol. vi. 135 (1879); vii. 304 (1879); viii. 157 (1879).

[9] *On the Causes of the Phenomena of Terrestrial Magnetism*, Pamphlet, 1890, p. 2. The idea that the Earth's magnetism is due to the electricity generated by the friction between the shell and the core, rotating with a different ...ion, was suggested by Dr. Wilde in 1902 (*Mem. Manch. Lit. and Phil. Soc.*, Profess... Part IV. p. 8, 1902). A similar suggestion based also on Halley's con... (*Mitth. G*... a separately rotating inner core was made previously by Sir F. J. Oldham has ...78 ('Remarkable Changes in the Earth's Magnetism,' *Nature*, vol. 62, 1900, p...

...*urn. Geol. Soc.*, vol. 63, 344-350 (1907).

indication of a difference between the physical nature of the sub-oceanic and sub-continental parts of the crust is in rough correspondence with the conclusions previously suggested on quite other grounds.

In his Presidential Address to the Geographical Section of the British Association at Dover in 1899, the late Sir John Murray drew attention to the chemical differentiation which has been going on between the continents and the oceans since the processes of weathering and denudation commenced. By these processes the more siliceous and specifically lighter constituents are left behind on the continents, while the heavier bases are carried out to the ocean. It is to this process that Professor T. C. Chamberlin [11] also ascribes the origin of the depressions in which the oceanic waters have accumulated. As a corollary of the planetesimal theory, Chamberlin assumes that water began to be forced out of the porous surface blocks of the accumulated meteoritic material when the Earth's radius was between 1,500 and 1,800 miles shorter than it is now; at that time pools of water began to be formed on the surface, and the atmosphere, just commencing its work, began the operation of leaching the heavier bases out of the highlands. Growth of the world proceeded by the infall of planetesimals, and while those meteorites that fell on the highlands became deprived of their soluble bases, those that fell into the young ocean were merely buried unaltered. Thus, by the time the Earth reached its present size its crust under the oceanic depressions must have developed a chemical composition differing from that under the continents. According to the deduction suggested by Oldham from the seismographic records, there is a noticeable difference in the sub-oceanic areas to depths of between 1,000 and 1,300 miles—a layer in which the followers of Chamberlin's theory might reasonably expect some physical expression of the partially developed chemical differentiation.

The occurrence of denser material below the oceans has, of course, long been assumed from the deflection of the plumb-line, and was accepted by Pratt for his theory of compensation, as well as by Dutton as a wide expression of the theory of isostasy. Chamberlain [12] thus explains the general prevalence of basic lavas in oceanic volcanoes.

The apparent heterogeneity indicated in the outer shell of the Earth to depths of 1,000 miles is naturally in conflict with the assumption that from thirty miles or so down the materials are in a liquid condition; at any rate, the idea conflicts with Fisher's extreme conception of the liquid substratum, in which the fluidity is supposed to be sufficient for the production of convection currents, upwards beneath the oceanic depressions, spreading horizontally towards the continents, and thence downwards to complete the circuit.

The idea that changes of azimuth and of latitude may be brought about by the sliding of the Earth's crust over its core has been put forward more than once to account for the climatic changes of past geological ages—the occurrence of temperate or even warm climates on parts of the crust now within the polar circles, and glacial conditions at the sea-level in countries like India, Australia, Africa, and South America, which are now far from the polar ice-sheets and in some cases near or within the tropics. Professor E. Koken, of Tübingen,[13] in an elaborate memoir entitled 'Indisches Perm und die Permische Eiszeit,' attributes the idea of a sliding crust to Mr. R. D. Oldham; but a similar suggestion was put forward by the late Sir John Evans twenty years before the publication of Mr. Oldham's paper,[14] and when the theory was restated in more precise form, ten years later,[15] it was subjected to mathematical criticism by J. F. Twisden, E. Hill, and O. Fisher.[16]

[11] Chamberlin and Salisbury, *Geology*, vol. ii. 1906, 106-111.

[12] *Geology*, ii. 1906, p. 120.

[13] *N. Jahrb. für Min. u.s.w.*, 1907, 537.

[14] J. Evans, 'On a possible Geological Cause of Changes in the Position of the Axis of the Earth's Crust,' *Proc. Roy. Soc.*, xv. 46 (1866).

[15] J. Evans, Presidential Address, *Proc. Geol. Soc.*, 1876, p. 105.

[16] J. F. Twisden, 'On possible Displacements of the Earth's Axis of figure produced by Elevations and Depressions of her Surface,' *Quart. Journ. Geol. Soc.*, xxxiv. 35 (1877). E. Hill, 'On the possibility of Changes in the Earth's Axis,' *Geol. Mag.*, 1878, 262 and 479. O. Fisher, 'On the possibility of Changes in the Latitude of Places on the Earth's Surface,' *Geol. Mag.*, 1878, pp. 291 and 551.

Sir John Evans suggested that this movement of the crust was inevitable as a consequence of the moulding of the orographical features and consequent redistribution of weights; but Twisden came to the conclusion that the re-arrangement of the great inequalities on the Earth's surface would be insufficient to produce any appreciable sliding of the order required to make material differences in the climate of any place.

Oldham,[17] who was writing at the time in the field in India and thus away from literature, put forward the idea in 1886 as an independent thought, and made use of Fisher's new theory regarding the existence of a fluid stratum between the solid crust and the supposed solid core to account for the shifting of places relative to the axis of rotation from the equatorial region even to the polar circles. Oldham drew attention to the recorded small changes of latitude at certain observatories and to the probable changes of azimuth in the Pyramids of Egypt—evidences of a kind which have since been greatly enlarged by the work of Sir Norman Lockyer and others.

The movements assumed to have taken place during the human period are of course small; and to project from them changes as great as the transfer of lands from the polar circle to the tropics has the objection that characterises a surveyor's use of 'unfavourable' triangles in a trigonometrical survey. Before admitting, therefore, that these small changes of latitude and of azimuth may be classed with the palæo-glacialists' evidence as data of the same kind, though so utterly different in magnitude, it is desirable briefly to examine the geological evidence regarding past ice-ages in extra-polar areas.

From the records of ancient glaciations we might omit those of the pre-Cambrian rocks of North Ontario and the pre-Upper Cambrian of Norway, as these areas are nearer the poles than many places which were certainly covered with ice-sheets during the youngest, or often so called Great, Ice Age. But besides these we have evidence of glaciation in the Cambrian or possibly pre-Cambrian rocks of South Australia at a latitude of 35° or less; in South Africa there were two or more distinct glacial periods before Lower Devonian times in slightly lower latitudes; while in China similar records are found among rocks of the Lower Cambrian, or possibly of older age, at a latitude of 31° N.

The glacial boulder-beds found at the base of our great coal-bearing system in India belong to the same stratigraphical horizon as the glacial beds found in South Africa, certain parts of Australia, and in parts of Brazil and São Paulo near or within the southern tropic.

These glacial beds are often referred to in geological literature as Permo-Carboniferous in age; but Professor Koken regarded the formation in India as Permian. Other valuations of palæontological evidence, similar to that relied on by Professor Koken, place these beds at a distinctly lower horizon in the European stratigraphical scale, and recent work by officers of the Geological Survey of India in Kashmir tends to confirm this latter view; we now regard the base of our great coal-bearing system in India—the horizon of the glacial-boulder-beds—as not much, if at all, younger than the Upper Coal Measures of Britain.[18] The precise age of the horizon is not very important for our present consideration: the important point is that in or near Upper Carboniferous times a wide-spread glaciation occurred throughout the area now occupied by India, Australia, and South Africa. The records of this great glaciation are thus found stretching northwards beyond the northern as well as southwards beyond the southern tropic.

Now, on the assumption that the cold climate in this region was due to a movement of the crust over the nucleus, Professor Koken has produced an elaborate map of the World, showing the distribution of land and sea during the period, with the directions of ocean-currents and of ice-sheets. The Permian South Pole he places at the point of intersection of the present 20th parallel S. and 80th meridian E.—that is, at a point in the Indian Ocean about equidistant from the glaciated regions of India, Australia, and South Africa. The Permian North Pole is thus forced to take up its position in the centre of Mexico, while the Equator strikes through Russia, Italy, West Africa, down through the South Atlantic and round by Fiji to Vladivostock.

[17] *Geol. Mag.*, 1886, 304.
[18] H. H. Hayden, *Rec. Geol. Surv. Ind.*, vol. xxxvi. p. 23, 1907.

The very precision of this map reduces the theory on which it is based to a condition of unstable equilibrium. If glacial conditions were developed in India, Australia, and South Africa by a 70° movement of the crust, were the movements to and from its assumed position in Permian times so rapid that the glaciation of these widely separated areas appears to be geologically contemporaneous? If such movements had occurred, instead of evidences of glaciation over a wide area at the *same* period, we ought rather to find that the glaciation in each of the widely separated points occurred during distinctly *different* geological periods.

But that is not the only weak spot in the evidence. The Permian (or Permo-Carboniferous) glaciation of Australia took place on the east and south-east of the continent as well as in Western Australia, and the eastern ice-sheets would thus have been active within 30° of Professor Koken's Permian equator. There are still three other serious pieces of colour-discord in this picture. In the State of São Paulo—that is, within Koken's 'Permian' tropics—Dr. Orville Derby has described beds which strikingly recall the features of the Upper Palæozoic glacial beds of India and South Africa. It is possible that these are due to the work of glaciers at a high level; but, since the publication of Professor Koken's memoir, other occurrences of the kind have been described by Dr. I. C. White in different parts of Brazil, and there is a general correspondence between the phenomena in South America and those in the formations of the same age in the Indian, Australian, and African regions.

Then, too, if we accept this expression of the physical geography during Upper Palæozoic times, we must carefully explain away the suspicious breccias and brockrams which have been regarded by many geologists as evidences of a cold climate during Permian times in the Urals, the Thuringerwald, the English Midland and Northern counties, Devonshire and Armagh—places that would lie on or near Koken's 'Permian' equator. Finally, we find the hypothetical Permian North Pole in a locality which has failed to produce any signs of glaciation.

To attempt a discussion of the explanations offered to account for the great Upper Palæozoic glaciation would lead us far from the present theme. The question is raised merely to show that the phenomena are not consistent with the supposed movement of a solid shell over a solid core assisted by an intermediate molten lubricant. Geologists may be compelled to hand back the theory of a molten substratum to the mathematicians and physicists for further repair; but it does not necessarily follow that a foundation theory is unsound merely because it has been overloaded beyond its compressive strength.

The extraordinarily great distances between the areas that show signs of glaciation in Permo-Carboniferous times form a serious stumbling-block to most of the explanations which have hitherto been offered. One is almost tempted in despair even to ask if it is not possible that these fragments of the old Gondwana continent are now more widely separated from one another than they were in Upper Palæozoic times. It is a bold suggestion indeed that one can safely put aside as absurd in geomorphology. There is nothing else apparently left for us but the assumption of a general refrigeration.

The idea of the greater inequalities of the globe being in approximately static equilibrium has been recognised for many years: it was expressed by Babbage and Herschel; it was included in Archdeacon Pratt's theory of compensation; and it was accepted by Fisher as one of the fundamental facts on which his theory of mountain structure rested. But in 1889 Captain C. E. Dutton presented the idea 'in a modified form, in a new dress, and in greater detail'; he gave the idea orthodox baptism and a name, which seems to be necessary for the respectable life of any scientific theory. 'For the condition of equilibrium of figure, to which gravitation tends to reduce a planetary body, irrespective of whether it be homogeneous or not,' Dutton[19] proposed 'the name *isostasy*.' The corresponding adjective would be isostatic—the state of balance between the ups and downs on the Earth.

For a long time geologists were forced to content themselves with the conclusion that the folding of strata is the result of the crust collapsing on a cooling

[19] Dutton, 'On some of the Greater Problems of Physical Geology,' *Bull. Phil. Soc. Wash.*, xi. 53, 1889.

and shrinking core; but Fisher pointed out that the amount of radial shrinking could not account even for the present great surface inequalities of the lithosphere, without regard to the enormous lateral shortening indicated by the folds in great mountain regions, some of which, like the Himalayan folds, were formed at a late date in the Earth's history, folds which in date and direction have no genetic relationship to G. H. Darwin's primitive wrinkles. Then, besides the folding and plication of the crust in some areas, we have to account for the undoubted stretching which it has suffered in other places, stretching of a kind indicated by faults so common that they are generally known as normal faults. It has been estimated by Claypole that the folding of the Appalachian range resulted in a horizontal compression of the strata to a belt less than 65 per cent. of the original breadth. According to Heim the diameter of the northern zone of the central Alps is not more than half the original extension of the strata when they were laid down in horizontal sheets. De la Beche, in his memoir on Devon and Cornwall, which anticipated many problems of more than local interest, pointed out that, if the inclined and folded strata were flattened out again, they would cover far more ground than that to which they are now restricted on the geological map. Thus, according to Dutton, Fisher, and others, the mere contraction of the cooling globe is insufficient to account for our great rock-folds, especially great folds like those of the Alps and the Himalayas, which have been produced in quite late geological times. It is possible that this conclusion is in the main true; but in coming to this conclusion we must give due value to the number of patches which have been let into the old crustal envelope—masses of igneous rock, mineral veins and hydrated products which have been formed in areas of temporary stretching, and have remained as permanent additions to the crust, increasing the size and bagginess of the old coat, which, since the discovery of radium, is now regarded as much older than was formerly imagined by non-geological members of the scientific world.

The peculiar nature of rock folds presents also an obstacle no less formidable from a qualitative point of view. If the skin were merely collapsing on its shrinking core we should expect wrinkles in all directions; yet we find great folded areas like the Himalayas stretching continuously for 1,400 miles, with signs of a persistently directed overthrust from the north; or we have folded masses like the Appalachians of a similar order of magnitude stretching from Maine to Georgia, with an unmistakable compression in a north-west to south-east direction. The simple hypothesis of a collapsing crust is thus 'quantitatively insufficient,' according to Dutton, though this is still doubtful, and it is 'qualitatively inapplicable,' which is highly probable.

In addition to the facts that rock-folds are maintained over such great distances and that later folds are sometimes found to be superimposed on older ones, geologists have to account for the conditions which permit of the gradual accumulation of enormous thicknesses of strata without corresponding rise of the surface of deposition.

On the other hand, too, in folded regions there are exposures of beds superimposed on one another with a total thickness of many miles more than the height of any known mountain, and one is driven again to conclude that uplift has proceeded *pari passu* with the removal of the load through the erosive work of atmospheric agents.

It does not necessarily follow that these two processes are the direct result of loading in one case and of relief in the other; for slow subsidence gives rise to the conditions that favour deposition and the uplifting of a range results in the increased energy of eroding streams.

Thus there was a natural desire to see if Dutton's theory agreed with the variations of gravity. If the ups and downs are balanced, the apparently large mass of a mountain-range ought to be compensated by lightness of material in and below it. Dutton was aware of the fact that this was approximately true regarding the great continental plateaux and oceanic depressions; but he imagined that the balance was delicate enough to show up in a small hill-range of 3,000 to 5,000 feet.

The data required to test this theory, accumulated during the triangulation of the United States, have been made the subject of an elaborate analysis by

J. F. Hayford and W. Bowie.[20] They find that, by adopting the hypothesis of isostatic compensation, the differences between the observed and computed deflections of the vertical caused by topographical inequalities are reduced to less than one-tenth of the mean values which they would have if no isostatic compensation existed. According to the hypothesis adopted, the inequalities of gravity are assumed to die out at some uniform depth, called the depth of compensation, below the mean sea-level. The columns of crust material standing above this horizon vary in length according to the topography, being relatively long in highlands and relatively short under the ocean. The shorter columns are supposed to be composed of denser material, so that the product of the length of each column by its mean density would be the same for all places. It was found that, by adopting 122 kilomètres as the depth of compensation, the deflection anomalies were most effectually eliminated, but there still remained unexplained residuals or local anomalies of gravity to be accounted for.

Mr. G. K. Gilbert,[21] who was one of the earliest geologists to turn to account Dutton's theory of isostasy, has recently offered a plausible theory to account for these residual discrepancies between the observed deflections and those computed on the assumption of isostatic compensation to a depth of 122 kilomètres. An attempt had already been made by Hayford and Bowie to correlate the distribution of anomalies with the main features of the geological map and with local changes in load that have occurred during comparatively recent geological times. For example, they considered the possibility of an increased load in the lower Mississippi valley, where there has been in recent times a steady deposition of sediment, and therefore possibly the accumulation of mass slightly in advance of isostatic adjustment. One would expect in such a case that there would be locally shown a slight excess of gravity, but, on the contrary, there is a general prevalence of negative anomalies in this region. In the Appalachian region, on the other hand, where there has been during late geological times continuous erosion, with consequent unloading, one would expect that the gravity values would be lower, as isostatic compensation would naturally lag behind the loss of overburden; this, however, is also not the case, for over a greater part of the Appalachian region the anomalies are of the positive order. Similarly, in the north central region, where there has been since Pleistocene times a removal of a heavy ice-cap, there is still a general prevalence of positive anomalies.

These anomalies must, therefore, remain unexplained by any of the obvious phenomena at the command of the geologist. G. K. Gilbert now suggests that, while it may be true that the product of the length of the unit column by its mean density may be the same, the density variations within the column may be such as to give rise to different effects on the pendulum. If, for instance, one considers two columns of the same size and of exactly the same weight, with, in one case, the heavy material at a high level and in the other case with the heavy material at a low level, the centre of gravity of the former column, being nearer the surface, will manifest itself with a greater pull on the pendulum; these columns would be, however, in isostatic adjustment.[22]

[20] J. F. Hayford, 'The Figure of the Earth and Isostasy,' *U.S. Coast and Geodetic Survey*, Washington, 1909. 'Supplementary Investigation,' Washington, 1910. See also *Science*, New Series, vol. xxxiii., p. 199, 1911. J. F. Hayford and W. Bowie, 'The Effect of Topography and Isostatic Compensation upon the Intensity of Gravity,' *U.S. Coast and Geodetic Survey Special Publication* No. 10, Washington, 1912.

[21] 'Interpretation of Anomalies of Gravity,' *U.S. Geol. Surv. Professional Paper* 85-C, 1913, p. 29.

[22] It is interesting to note that the idea suggested by G. K. Gilbert in 1913 was partly anticipated by Major H. L. Crosthwait in 1912 (*Survey of India, Professional Paper* No. 13, p. 5). Major Crosthwait in discussing the similar gravity anomalies in India remarks parenthetically: 'Assuming the doctrine of isostasy to hold, is it not possible that in any two columns of matter extending from the surface down to the depth of compensation there may be the same mass, and yet that the density may be very differently distributed in the two

Gilbert's hypothesis thus differs slightly from the conception put forth by Hayford and Bowie; for Gilbert assumes that there is still appreciable heterogeneity in the more deep-seated parts of the Earth, while Hayford and Bowie's hypothesis assumes that in the nuclear mass density anomalies have practically disappeared, and that there is below the depth of compensation an adjustment such as would exist in a mass composed of homogeneous concentric shells.

In order to make the Indian observations comparable to those of the United States as a test of the theory of isostasy, Major H. L. Crosthwait [23] has adopted Hayford's system of computation and has applied it to 102 latitude stations and 18 longitude stations in India. He finds that the unexplained residuals in India are far more pronounced than they are in the United States, or, in other words, it would appear that isostatic conditions are much more nearly realised in America than in India.

The number of observations considered in India is still too small for the formation of a detailed map of anomalies, but the country can be divided into broad areas which show that the mean anomalies are comparable to those of the United States only over the Indian peninsula, which, being a mass of rock practically undisturbed since early geological times, may be regarded safely as having approached isostatic equilibrium. To the north of the peninsula three districts form a wide band stretching west-north-westwards from Calcutta, with mean residual anomalies of a positive kind, while to the north of this band lies the Himalayan belt, in which there is always a large negative residual.

Colonel Burrard [24] has considered the Himalayan and Sub-Himalayan anomalies in a special memoir, and comes to the conclusion that the gravity deficiency is altogether too great to be due to a simple geosynclinal depression filled with light alluvium such as we generally regard the Gangetic trough to be. He suggests that the rapid change in gravity values near the southern margin of the Himalayan mass can be explained only on the assumption of the existence of a deep and narrow rift in the sub-crust parallel to the general Himalayan axis of folding. A single large rift of the kind and size that Colonel Burrard postulates is a feature for which we have no exact parallel; but one must be careful not to be misled by the use of a term which, while conveying a definite mental impression to a mathematician, appears to be incongruous with our geological experience. There may be no such thing as a single large rift filled with light alluvial material, but it is possible that there may still be a series of deep-seated fissures that might afterwards become filled with mineral matter.

With this conception of a rift or a series of rifts, Colonel Burrard is led to reverse the ordinary mechanical conception of Himalayan folding. Instead now of looking upon the folds as due to an overthrust from the north, he regards the corrugations to be the result of an under-creep of the sub-crust towards the north. Thus, according to this view, the Himalaya, instead of being pushed over like a gigantic rock-wave breaking on to the Indian *Horst*, is in reality being dragged away from the old peninsula, the depression between being filled up gradually by the Gangetic alluvium. So far as the purely stratigraphical features are concerned, the effect would be approximately the same whether there is a superficial overthrust of the covering strata or whether there is a deep-seated withdrawal of the basement which is well below the level of observation.

Since the Tibetan expedition of ten years ago we have been in possession of definite facts which show that to the north of the central crystalline axis of the Himalaya there lies a great basin of marine sediments forming a fairly complete record from Palæozoic to Tertiary times, representing the sediments

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columns? These two columns, though in isostatic equilibrium, would act differently on the plumb-line owing to the unequal distribution of mass.

'The drawback to treating this subject by hard and fast mathematical formulæ is that we are introducing into a discussion of the constitution of the earth's crust a uniform method when, in reality, probably no uniformity exists.'

[23] *Survey of India, Professional Paper* No. 13, 1912.

[24] *Ibid.* No. 12, 1912.

which were laid down in the great central Eurasian ocean to which Suess gave the name *Tethys*. We have thus so far been regarding the central crystalline axis of the Himalaya as approximately coincident with the old northern coast-line of Gondwanaland; but, if Colonel Burrard's ideas be correct, the coast-line must have been very much further to the south before the Himalayan folding began.

Representing what the Geological Survey of India regards as the orthodox view, Mr. H. H. Hayden [25] has drawn attention to some conclusions which, from our present geological knowledge, appear to be strange and improbable in Colonel Burrard's conclusions, and he also offers alternative explanations for the admitted geodetic facts. Mr. Hayden suggests, for instance, that the depth of isostatic compensation may be quite different under the Himalayan belt from that under the regions to the south. His assumptions, however, in this respect are, as pointed out by Colonel G. P. Lenox Conyngham,[26] at variance with the whole theory of isostasy. Mr. Hayden then suggests that most of the excessive anomalies would disappear if we took into account the low specific gravity of the Sub-Himalayan sands and gravels of Upper Tertiary age as well as of the Pleistocene and recent accumulations of similar material filling the Indo-Gangetic depression. It would not be at all inconsistent with our ideas derived from geology to regard the Gangetic trough as some three or four miles deep near its northern margin, thinning out gradually towards the undisturbed mass of the Indian peninsula, and Mr. R. D. Oldham,[27] with this view, has also calculated the effect of such a wedge of alluvial material of low specific gravity, coming to the conclusion that the rapid change in deflection, on passing from the Lower Himalaya southward towards the peninsula, can mainly be explained by the deficiency of mass in the alluvium itself.

It is obvious that, before seeking for any unusual cause for the gravity anomalies, we ought to take into account the effect of this large body of alluvium which lies along the southern foot of the range. It is, however, by no means certain that a thick mass of alluvial material, accumulated slowly and saturated with water largely charged with carbonate of lime, would have a specific gravity so appreciably lower than that of the rocks now exposed in the main mass of the Himalaya as to account for the residual anomalies. Some of the apparent deficiency in gravity is due to this body of alluvium, but it will only be after critical examination of the data and more precise computation that we shall be in a position to say if there is still room to entertain Colonel Burrard's very interesting hypothesis.

By bringing together the geological and geodetic results we notice five roughly parallel bands stretching across northern India. There is (1) a band of abnormal high gravity lying about 150 miles from the foot of the mountains, detected by the plumb-line and pendulum; (2) the great depression filled by the Gangetic alluvium; (3) the continuous band of Tertiary rock, forming the Sub-Himalaya, and separated by a great boundary overthrust from (4) the main mass of the Outer and Central Himalaya of old unfossiliferous rock, with the snow-covered crystalline peaks flanked on the north by (5) the Tibetan basin of highly fossiliferous rocks formed in the great Eurasian mediterranean ocean that persisted up to nearly the end of Mesozoic times.

That these leading features in North India can hardly be without genetic relationship one to another is indicated by the geological history of the area. Till nearly the end of the Mesozoic era the line of crystalline, snow-covered peaks now forming the Central Himalaya was not far from the shore-line between Gondwanaland, stretching away to the south, and Tethys, the great Eurasian ocean. Near the end of Mesozoic times there commenced the great outwelling of the Deccan Trap, the remains of which, after geological ages of erosion, still cover an area of 200,000 square miles, with a thickness in places of nearly 5,000 feet. Immediately after the outflow of this body of basic lava, greater in mass than any known eruption of the kind, the ocean flowed into North-West India and projected an arm eastwards to a little beyond the point

[25] *Rec. Geol. Surv. Ind.*, vol. xliii. part 2, p. 138, 1913.
[26] *Records of the Survey of India*, vol. v. p. 1.
[27] *Proc. Roy. Soc.*, Series A, vol. 90, p. 32, 1914.

at which the Ganges now emerges from the hills. Then followed the folding movements that culminated in the present Himalayan range, the elevation developing first on the Bengal side, and extending rapidly to the north-west until the folds extended in a great arc for some 1,400 miles from south-east to north-west.

New streams developed on the southern face of the now rising mass, and although the arm of the sea that existed in early Tertiary times became choked with silt, the process of subsidence continued, and the gradually subsiding depression at the foot of the hills as fast as it developed became filled with silt, sand, gravel, and boulders in increasing quantities as the hills became mountains and the range finally reached its present dimensions, surpassing in size all other features of the kind on the face of the globe.

Now, it is important to remember that for ages before the great outburst of Deccan Trap occurred there was a continual unloading of Gondwanaland, and a continual consequent overloading of the ocean bed immediately to the north; that this process went on with a gradual rise on one side and a gradual depression on the other; and that somewhere near and parallel to the boundary line the crust must have been undergoing stresses which resulted in strain, and, as I suggest, the development of those fissures that let loose the floods of Deccan Trap and brought to an end the delicate isostatic balance.

During the secular subsidence of the northern shore line of Gondwanaland, accompanied by the slow accumulation of sediment near the shore and the gradual filing away of the land above sea level, there must have been a gradual creep of the crust in a northerly direction. Near the west end of the Himalayan arc this movement would be towards the north-west for a part of the time; at the east end the creep would be towards the north-north-east and north-east. Thus there would be a tendency from well back in Palæozoic times up to the end of the Cretaceous period for normal faults--faults of tension—to develop on the land, with a trend varying from W.S.W.-E.N.E. to W.N.W.-E.S.E. across the northern part of Gondwanaland. We know nothing of the evidence now pigeon-holed below the great mantle of Gangetic alluvium, while the records of the Himalayan region have been masked or destroyed by later foldings. But in the stratified rocks lying just south of the southern margin of the great alluvial belt we find a common tendency for faults to strike in this way across the present Peninsula of India. These faults have, for instance, marked out the great belt of coalfields stretching for some 200 miles from east to west in the Damuda valley. On this, the east side of India, the fractures of tension have a general trend of W.N.W.-E.S.E. We know that these faults are later than the Permian period, but some of them certainly were not much later.

If now we go westwards across the Central Provinces and Central India and into the eastern part of the Bombay Presidency, we find records of this kind still more strikingly preserved; for where the Gondwana rocks, ranging from Permo-Carboniferous to Liassic in age, rest on the much older Vindhyan series, we find three main series of these faults. One series was developed before Permo-Carboniferous times; another traverses the lower Gondwanas, which range up to about the end of Permian times; while the third set affects the younger and Upper Gondwanas of about Rhætic or Liassic age. Although the present topography of the country follows closely the outlines of the geological formations, it is clear from the work of the Geological Survey of India that these outlines were determined in Mesozoic times, and that the movements which formed the latest series of faults were but continuations of those which manifested themselves in Palæozoic times. According to Mr. J. G. Medlicott, the field data showed 'that a tendency to yield in general east and west or more clearly north-east and south-west lines existed in this great area from the remote period of the Vindhyan fault.'[28] The author of the memoir and map on this area was certainly not suspicious of the ideas of which I am now unburdening my mind; on the contrary, he attempted and, with apologies, failed to reconcile his facts to views then being pushed by the weight of 'authority' in Europe. This was not the last time that facts established in India were found (to use a field-geologist's term) unconformably to lie on a basement of

[28] *Mem. Geol. Surv. Ind.*, vol. ii. 1860, part 2, p. 256.

geological orthodoxy as determined by authority in Europe. It is important to notice that the series of faults referred to in the central parts of India are not mere local dislocations, but have a general trend for more than 250 miles.

A fault must be younger, naturally, than the strata which it traverses, but how much younger can seldom be determined. Intrusive rocks of known age are thus often more useful in indicating the age of the fissures through which they have been injected, and consequently the dykes which were formed at the time of the eruption of the great Deccan Trap give another clue to the direction of stresses at this critical time, that is towards the end of the Cretaceous period, when the northerly creep had reached its maximum, just before Gondwanaland was broken up. If, now, we turn to the geological maps of the northern part of Central India, the Central Provinces, and Bengal, we find that the old Vindhyan rocks of the Narbada valley were injected with hundreds of trap-dykes which show a general W.S.W.-E.N.E. trend, and thus parallel to the normal tension faults, which we know were formed during the periods preceding the outburst of the Deccan Trap. This general trend of faults and basic dykes is indicated on many of the published geological maps of India covering the northern part of the peninsula, including Ball's maps of the Ramgarh and Bokaro coalfields [29] and of the Hutar coalfield,[30] Hughes' Rewa Gondwana basin,[31] Jones' southern coalfields of the Satpura basin,[32] and Oldham's general map of the Son Valley.[33]

We see, then, that the development of fissures with a general east-west trend in the northern part of Gondwanaland culminated at the end of the Cretaceous period, when they extended down, probably, to the basic magma lying below the crust either in a molten state, or in a state that would result in fluxion on the relief of pressure. That the molten material came to the surface in a superheated and liquid condition is shown by the way in which it has spread out in horizontal sheets over such enormous areas. Throughout this great expanse of lava there are no certain signs of volcanic centres, no conical slopes around volcanic necks; and one might travel for more than 400 miles from Poona to Nagpur over sheets of lava which are still practically horizontal. There is nothing exactly like this to be seen elsewhere to-day. The nearest approach to it is among the Hawaiian calderas, where the highly mobile basic lavas also show the characters of superfusion, glowing, according to J. D. Dana,[34] with a white heat, that is, at a temperature not less than about 1,300°C.

Mellard Reade has pointed out that the Earth's crust is under conditions of stress analogous to those of a bent beam, with, at a certain depth, a 'level of no strain.' Above this level there should be a shell of compression, and under it a thicker shell of tension. The idea has been treated mathematically by C. Davison, G. H. Darwin, O. Fisher, and M. P. Rudski, and need not be discussed at present. Professor R. A. Daly has taken advantage of this view concerning the distribution of stresses in the crust to explain the facility for the injection of dykes and batholiths from the liquid, or potentially liquid, gabbroid magma below into the shell of tension.[35] He also shows that the injection of large bodies of basic material into the shell of tension tends on purely mechanical grounds to the formation of a depression, or geosyncline. If this be so, are we justified in assuming that the heavy band following the southern margin of the Gangetic geosyncline is a 'range' of such batholiths? The idea is not entirely new; for O. Fisher made the suggestion more than twenty years ago that the abnormal gravity at Kalianpur was due to 'some peculiar influence (perhaps of a volcanic neck of basalt).'[36]

[29] *Mem. Geol. Surv. Ind.*, vol. vi. part 2.
[30] *Ibid.*, vol. xv.
[31] *Ibid.*, vol. xxi. part 3.
[32] *Ibid.*, vol. xxiv.
[33] *Ibid.*, vol. xxxi. part 1.
[34] *Characteristics of Volcanoes*, 1891, p. 200.
[35] R. A. Daly, 'Abyssal Igneous Injection as a Causal Condition and as an Effect of Mountain-building,' *Amer. Journ. Sci.*, xxii. Sept. 1906, p. 205.
[36] *Physics of the Earth's Crust*, 2nd ed., 1889, p. 216.

Daly's suggestion, however, taken into account with the history of Gondwanaland, may explain the peculiar alignment of the heavy subterranean band, parallel to the Gangetic depression and parallel to the general trend of the peninsular tension-faults and fissures that followed the unloading of Gondwanaland and the heavy loading of the adjoining ocean bed along a band roughly parallel to the present Himalayan folds.

R. S. Woodward objected that isostasy does not seem to meet the requirements of geological continuity, for it tends rapidly towards stable equilibrium, and the crust ought therefore to reach a stage of repose early in geologic time.[37] If the process of denudation and rise, with adjoining deposition and subsidence, occurred on a solid globe, this objection might hold good. But it seems to me that the break-up of Gondwanaland and the tectonic revolutions that followed show how isostasy can defeat itself in the presence of a sub-crustal magma actually molten or ready to liquefy on local relief of pressure. It is possible that the protracted filing off of Gondwanaland brought nearer the surface what was once the local level of no-strain and its accompanying shell of tension.

The conditions existing in northern Gondwanaland before late Mesozoic times must have been similar to those in south-west Scotland before the occurrence of the Tertiary eruptions, for the crust in this region was also torn by stresses in the S.W.–N.E. direction with the formation of a remarkable series of N.W.–S.E. dykes which give the one-inch geological maps in this region a regularly striped appearance.

There is no section of the Earth's surface which one can point to as being now subjected to exactly the same kind and magnitude of treatment as that to which Gondwanaland was exposed for long ages before the outburst of the Deccan Trap; but possibly the erosion of the Brazilian highlands and the deposition of the silt carried down by the Amazon, with its southern tributaries, and by the more eastern Araguay and Tocantins, may result in similar stresses which, if continued, will develop strains, and open the way for the subjacent magma to approach the surface or even to become extravasated, adding another to the small family of so-called fissure-eruptions.

The value of a generalisation can be tested best by its reliability as a basis for prediction. Nothing shows up the shortcomings of our knowledge about the state of affairs below the superficial crust so effectually as our inability to make any useful predictions about earthquakes or volcanic eruptions. For many years to come in this department of science the only worker who will ever establish a claim to be called a prophet will be one in Cicero's sense—'he who guesses well.'

MELBOURNE.

FRIDAY, AUGUST 14.

The following Papers were read :—

1. *The Geology of Victoria.* *By* Professor ERNEST W. SKEATS, *D.Sc.*

2. *Exhibition of a Series of Lantern Slides illustrating Desert Scenery and Denudation.* *By* Dr. JOHANNES WALTHER.

Every climatic region is characterised by a different type of disintegration and denudation of soft or softened rock by the agents of erosion. In the nival region a cover of snow protects the surface of the earth during a long period of the year.

In the humid zone and also in the equatorial pluvial region the soil is over-

[37] 'Address to the Sect. of Mathematics and Astronomy of the Amer. Assoc.,' 1889. *Smithsonian Report*, 1890, p. 196.

grown by a network of roots and rootlets of millions of plants, which bind together the small particles and protect them against wind and running water.

In arid regions, where the rain is not sufficient to form perennial rivers, and where the vegetation forms isolated patches in the barren country, every particle of soft or disintegrated rock is quickly taken away by the wind or the occasional rainfall. Therefore the general denudation of the land is very powerful. The Egyptian monuments, exposed during 4,000 years to the disintegrating and denuding powers of the desert, offer beautiful examples of the different kinds of dry disintegration, and many of them show very clearly also the transporting effect of the wind.

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3. *The Climatic Conditions of the Early Pre-Cambrian.* *By* Professor A. P. Coleman, *F.R.S.*

Our knowledge of the later Pre-Cambrian permits us to speak of desert conditions in the Keweenawan or Torridonian and of an ice age followed by a cool climate in the Huronian, but little evidence has been given as to earlier climates. Recent work in Canada shows that the Sudbury series, of Pre-Laurentian age and very much older than the Huronian, includes all types of sediments, often well enough preserved to show cross bedding, ripple marks, and annual layers indicating the change of seasons. They must have been formed near the margin of a continent where granites weathered under a cool and moist climate. They seem to be delta materials deposited by great rivers.

The highly metamorphosed sediments of the still older Grenville and Keewatin series (Lewisian ?) have lost their original structures, but the gneisses, quartzites, and marbles must have been clay, sand, and limestone in the beginning, and the graphite may have originated in plants. Land surfaces must have been attacked by water and air to produce these materials, and there is no evidence that the climate was hot. These are the earliest-known formations, so that air and water worked in the usual way at the beginning of recorded geological time.

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4. *Victorian Graptolites.* *By* T. S. Hall, *M.A.*, *D.Sc.*

The Silurian and Ordovician graptolite-bearing rocks of Victoria occupy about 20,000 square miles, and over a hundred species have been recorded.

Very little is known of the Silurian. The Ordovician is divided into Upper and Lower, but probably represents a continuous series. The Upper is characterised by the presence of Dicranograptidæ. No zonal work has been done in the field, though collections yielding about fifty recorded species have been made.

Four divisions are recognised in the Lower Ordovician, namely, Darriwillian, Castlemainian, Bendigonian, and Lancefieldian, at the base. There are several subdivisions of these formations. The characters were briefly indicated in the 'Geological Magazine' by the author in 1899. Subsequent work by T. S. Hart, F.G.S., at Daylesford has confirmed the sequence established. Large collections made by the Survey at many localities have somewhat extended our knowledge of the fauna and its distribution, but without adding any features of great importance.

The Upper Ordovician ranges north from Eastern Victoria for 300 miles into New South Wales. In New Zealand Lancefieldian occurs at Preservation Inlet, and two Castlemaine zones occur as well. It is probable that the Victorian sequence, and not the British as stated, will be found.

Broadly, the sequence of Australian graptolites agrees with the European, but in details is closer to that of New York, as Ruedemann has pointed out. The important differences in the range of *Didymograptus bifidus*, *D. caduceus*, *D. nicholsoni*, *Loganograptus*, *Clonograptus rigidus*, and some other genera and species negative the idea that graptolite zones are world-wide, and as no one believes that all genera and species originated in one locality and radiated thence this is what we should expect.

5. *On the Tertiary Alkali Rocks of Victoria.*
By Professor Ernest W. Skeats, *D.Sc.*

From Mount Leinster in Benambra, Frenchman's Hill near Omeo, and Noyang in Dargo, three areas in Eastern Victoria, the late Dr. Howitt (1) described igneous rocks which belong to the alkali series. They were all regarded by Howitt as of Palæozoic age. The age of the rocks of Noyang, which consist mainly of intrusions and lava-flows of quartz-ceratophyre, has not been closely investigated and may be Palæozoic. Recent work (2), however, has shown, especially in the case of the Omeo rocks, that they are probably of mid- or even of late-Tertiary age. The alkali rocks of Frenchman's Hill, described by Howitt as intrusive orthophyres, consist really in the main of lava-flows of anorthoclase trachyte which has a very scoriaceous margin to the flows. There is a central plug of a coarser quartz-bearing rock allied to sölvsbergite and a more or less radial system of dykes which are principally trachytic in character. Some, however, contain quartz, one at least is a bostonite, and six or seven prove to be dykes of nepheline-phonolite. The district is one which has been affected by a succession of elevatory movements of the plateau type since the mid-Tertiary period, and, according to Griffith Taylor (3), a more or less meridional Senkungsfeld runs through the Omeo district a few miles east of Frenchman's Hill. The rocks of Mount Leinster in Benambra consist principally of sölvsbergites, bostonites, and pyroclastic rocks of alkali trachyte. Petrologically and chemically many of the rocks of Mount Leinster and of Frenchman's Hill closely resemble some of the alkali rocks of Mount Macedon, and, like them, are probably of mid Tertiary age. The district has been elevated at intervals during the Tertiary period, but physiographically has not been closely studied.

About fourteen miles north-east from Mansfield in north-central Victoria and about three miles from Tolmie, in the Tolmie Highlands, there occurs a volcanic hill, known locally as Gallows Hill, which has recently been shown to consist of a volcanic centre of probably late Tertiary age and to consist of lava-flows of nepheline-phonolite. From a locality near Barwite, east of Mansfield, another nepheline-phonolite has been found, but its field relations are at present uncertain and no account of either of these rocks has yet been published. Fenner (4) has recently shown that block elevation and depression have affected the Mansfield area in recent geological times, and that Gallows Hill lies near one of the fault scarps.

The best-known area of alkali rocks in Victoria is the Mount Macedon district, about forty miles north-west of Melbourne (5). The series is of mid Tertiary to late-Tertiary age, and the rock sequence from below upwards, while not always demonstrable, appears to be as follows:—Anorthoclase trachyte, sölvsbergite, anorthoclase basalt, macedonite, woodendite, anorthoclase-olivine-trachyte, olivine-anorthoclase-trachyte, limburgite. Immediately succeeding these alkali rocks come lava-flows of normal basalt and of andesitic basalt. The new types macedonite and woodendite contain over 1 per cent. of P_2O_5, and are related to the orthoclase-basalts and to the mugearites.

While this part of Victoria shows evidence by the existence of more than one elevated peneplain of successive movements of the plateau type, no definite evidence of faulting or differential movement has been recognised in the district. In the western district of Victoria more or less extensive lava-flows of anorthoclase-trachyte occur near Coleraine, Carapook, &c. (6). Generally the trachytes appear to be older than the newer basalts, but near Coleraine a dyke of trachyte penetrates a small hill composed of a basic rock resembling olivine-basalt, while at the Hummocks north of Casterton another trachyte dyke similarly penetrates a vent or small flow of olivine-basalt. Among the ejected blocks from the earlier members of the Pleistocene newer basalts of Lake Bullenmerri, near Camperdown, are some consisting of essexite and containing analcite. In the western district of Victoria clear evidence of comparatively recent elevatory movements is noticeable. No definite faults have yet been proved, however, and the normal basalts are much more widely spread than the alkali rocks. In view of Harker's generalisation as to the close correspondence between the occurrence of alkali rocks and elevatory movements of the plateau type, generally accompanied by faulting, the above reference to earth movements is pertinent.

Practically no folding movements are known among the Tertiary rocks of Victoria, while plateau movements, generally of elevation, sometimes of depression and accompanied by faulting, are widespread. Near Omeo and Mansfield, where faulting has been demonstrated or inferred, the highly alkaline types of nepheline-phonolite are developed, but the widespread plateau movements in Victoria are more specially associated with the occurrence of the normal basalts. The alkali trachytes and allied rocks are intercalated between an older and a newer basalt series, are developed only sporadically at certain centres, and as at Macedon are closely associated in the field with the newer basalts as rocks of slightly greater antiquity but belonging to the same volcanic period.

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(3) Griffith Taylor, T. 'Com. Bureau of Meteorology,' Bulletin No. 8, 1911.
(4) Fenner, C. 'Proc. Roy. Soc. of Vict.,' vol. xxv. N.S., 1913.
(5) Gregory, J. W. 'Proc. Roy. Soc. of Vict.,' vol. xxv. N.S., 1901.
Skeats, E. W., and Summers, H. S. 'Geol. Surv. of Vict.' Bulletin No. 24, 1912.
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6. *On the Origin and Relationship of the Victorian Kainozoic Alkali Rocks. By* H. S. Summers, *D.Sc.*

Alkali rocks of Kainozoic age occur in Victoria in the Macedon District, near Coleraine and Carapook in the Western District, and in the neighbourhood of Omeo and Mansfield in North-Eastern Victoria. Ejected blocks from the volcanoes near Camperdown have been described as essexite, and a similar type, also probably ejected, has been found near Kyneton. With the exception of the occurrences of Omeo and Mansfield all these alkali rocks are closely associated with the Upper Kainozoic calcic basalts, and the field relations are such that there is little doubt that the alkali rocks and the basalts are genetically related.

Numerous analyses (mainly unpublished) have been made of Victorian basalts, and these show that they are fairly normal in composition, and consequently should belong to Harker's Calcic or Pacific Branch of Igneous rocks, whereas the sölvsbergites, trachytes, &c., of Macedon, the phonolites of Omeo and Mansfield, the essexites (?) of Camperdown and Kyneton, and the trachytes and anorthoclase-basalts of the Coleraine area must be placed in the Alkali or Atlantic Branch.

It follows then that the evidence of the Victorian Kainozoic rocks does not support Harker's generalisation on Petrographic Regions.

A number of first-class analyses has been made of the principal types of the Macedon series, and variation diagrams based on these analyses have been drawn. (See 'Bulletin of the Geol. Survey of Victoria,' No. 24, 1912, and 'Proceedings of the Royal Society of Victoria,' vol. xxvi. (N.S.), pt. ii. 1914.)

It was found that by re-calculating the analyses to 100 per cent. with the water omitted and the ferric oxide reduced to ferrous, the curves obtained were better than those plotted from the original analyses.

Certain of the analyses did not conform to the curves, and at first these were regarded as representing hybrid types, but additional work showed that they represented complementary types and resulted from the splitting up of a magma instead of the mixing of magmas.

Some analyses have been made of the alkali rocks from other Victorian areas, but not a sufficient number to show the relationship of the various types to one another.

The conclusions are that the Kainozoic alkali rocks of Victoria are derived from the calcic basalts by differentiation, giving rise to several lesser magma reservoirs.

In the case of the Macedon magma further differentiation took place and a series of lavas was extruded which in general showed a serial relationship, but some complementary to one another.

TUESDAY, AUGUST 18.

The following Papers were read :—

1. *The Permian Breccia of the Midland Counties of Britain, a Desert Formation. By* H. T. Ferrar, *M.A., F.G.S.*[1]

During the meeting of the Association at Birmingham last year members of this Section had an ample opportunity for visiting the chief exposures of the so-called Permian breccia of the midland counties of England. This deposit may be briefly described as a mass of sandstones and marls with occasional sheets of angular breccia, the latter consisting in a large measure of volcanic rocks, grits, slates, and limestones which can be identified with rocks on the borders of Wales. The organic remains which have been recorded are few, but such as occur are indicative chiefly of terrestrial surfaces.

The origin of the breccia has given rise to many speculations, amongst which may be mentioned :—

(1) Murchison (1839) regarded it as a volcanic or trappoid breccia marking the position of underground masses of volcanic rocks hidden under a cover of their own fragments.

(2) Ramsay (1855) ascribed its origin to the existence of glacial conditions in Permian times.

(3) Geikie (1892) says with regard to Scotland that the breccia has evidently accumulated in small lakes or narrow fiords during periods of great and rapid denudation following uplift of the Upper Carboniferous rocks.

(4) Bonney (1902) concludes that breccias are usually indicative of continental conditions, but that glaciers are necessary for the transport of the larger boulders.

(5) Lapworth (1912) holds that they are the memorials of local Alpine conditions.

In Egypt a chain of fold-mountains forms the watershed between the Nile and the Red Sea, and the mountains are intersected and drained by steep-sided gorges or wadis. The climate is arid with occasional heavy thunderstorms causing temporary torrents, which sweep forward all rock-material loosened during the prevailing dry climate. The wadi beds receive continuously a fresh supply of angular débris shed from the adjacent bare hillsides, and any fragments which may have become rounded or subangular are often shattered before the next flood sweeps them forward another stage on their journey towards a more permanent resting-place, namely, the alluvial plain at the wadi-mouth. Blocks slipping down the bare hillsides become scratched or they may be scratched by mutual impact during a sudden rush of flood-water. Great blocks are often carried fifty or one hundred miles down the wadi channels, and the agency of ice need not be invoked to explain their transport.

The valley-fill of most wadis in the Eastern Desert of Egypt is an unconsolidated breccia so similar to the breccia exposed on Ley Hill, near Birmingham, that there is little room for doubt that the two originated under similar climatic conditions

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[1] By permission of the Director-General, Egyptian Survey Department.

2. *Note on the Occurrence of Loess-deposits in Egypt and its Bearing on Change of Climate in recent Geological Times.*[1] *By* H. T. Ferrar, *M.A., F.G.S.*

At a recent meeting of the Association Dr. Hume and Mr. Craig submitted the view that there had been no change, except that of gradual desiccation, in recent geological times in Egypt. Since their paper was published, evidence that the change of climate has not been uniform has been recorded from neighbouring countries. The following short paper is intended to show how æolian desertic deposits may be interstratified between freshwater beds without any change of climate.

In the northern delta of Egypt are great stretches of flat land a few feet above sea-level. These areas are covered by ordinary Nile alluvium and remain damp during the winter months but dry in summer. Owing to the evaporation which takes place during the spring and early summer, soluble salts accumulate at or near the surface of the soil rendering it incoherent and powdery. Winds are now able to lift and transport this material until it is arrested by the roots of halophyte plants or other obstacles. Here also are deposited the dead shells of helices, and occasionally also the remains of land animals, such as the jackal, rat, bird, lizard, or snake, which have been seen frequenting dust-dune areas. In fact, the dust dunes of northern Egypt, known as Kardud to the inhabitants, are local deposits of Loess.

A depression of the land of only a few feet, and such as that which has taken place since Roman times in Egypt, would cause another fluviatile layer containing the common shell *Cyrena fluminalis* or a lacustrine bed to be superimposed upon them. It is thus manifest that a desertic deposit interstratified between two freshwater beds is not necessarily a proof of change of climate.

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3. *Discussion on the Physiography of Arid Lands.*

Introduction. By Professor Sir T. H. Holland, *K.C.I.E., D.Sc., F.R.S.*

The principal defect in published accounts of the physiography of arid lands is due to the absence of data showing the amount as well as the kind of physical changes in progress. This deficiency is to be expected. Few qualified observers are able to study arid lands for long continuous periods; such regions are thinly populated, and, from an economic point of view, their problems are of relatively small importance. It is not surprising, therefore, that, while we have abundant illustrations—pictorial and literary—regarding the nature of geological phenomena in the desert, we are only to a limited extent able to substantiate by trustworthy figures our general conclusions regarding the rates of destruction, transportation, and reproduction of desert formations.

The investigation made during the years 1903-08 of the salt resources of the Rajputana desert was undertaken on behalf of the Government of India with a definite economic object in view, and the opportunity was turned to account to make a quantitative test of one phase of desert phenomena—namely, the æolian transportation of salt in the form of fine dust.[2]

There are several intermittent saline lakes lying in depressions on the sand-covered highlands of Rajputana. In one case—namely, the Sambhar Lake—the underlying silt, tested to a depth of twelve feet over an area of 68 square miles, was found to contain some fifty-five million tons of sodium chloride. The quantities of salt so stored are altogether in excess of the amount that could be accumulated by normal fresh-water rivers acting within any reasonable geological period under present physiographic conditions. There are no rock-salt deposits known within the region under consideration, and the underlying rocks are Archæan gneisses and schists covered with a thin mantle of sand.

[1] By permission of the Director-General of the Egyptian Survey Department.
[2] For details see T. H. Holland: successive Annual Reports of the Geo. S. of India published in *Records G.S.I.* during 1904-09.

The discovery of small undamaged foraminifera in the desert sands of Barmer and Bikaner by Mr. T. H. D. La Touche [1] gave the first clue to the origin of this salt, for such foraminifera must have reached the heart of the desert by wind transportation over a distance of some five hundred miles from the coast of Cutch. Consideration of the meteorological conditions of the area increased the plausibility of this suggestion; for during the hot dry season, from April to June, strong winds blow from the south-west, sometimes with the force of gales, especially during the day-time, when, under a scorching sun, the salt is absolutely dry and easily powdered. The Rann of Cutch during the hot dry season partly dries up and becomes covered with a thin incrustation of salt, so that every traveller—man or beast—crushes the hopper-shaped skeleton crystals of sodium chloride, forming puffs of fine saline dust, which are wafted away by the strong winds to the north-east and towards the desert region of Rajputana. During the hot dry season these winds maintain a constant direction; they are strong during the day, moderating to a comparative calm at nights, but there is never a set-back, and they are followed every year by the rainy season, which commences about the middle of June.

These winds are specially strong near the coast, but they diminish in force in the central part of the desert region, and there their load of saline dust becomes deposited over the surface of the sand, being washed in solution into convenient hollows during the rainy season, thus forming small lakes, which become rapidly reduced to bodies of concentrated brine during the next following dry cold weather.

During the cold weather which follows the rainy season the atmosphere is dry, and winds blow generally from the north and north-east. These winds are, however, comparatively feeble, and in any case are unable to carry an appreciable quantity of salt back to the south-west, as the salt is by then accumulated in the lakes, which are seldom completely dry before the commencement of the next following hot weather, when the recurring south-west winds bring in another load of salt-dust.

By the elimination of all other possible sources of the salt in the lakes of the Rajputana highlands, and by consideration of the meteorological conditions, a satisfactory theory thus became established to account qualitatively for the origin of the salt. It then became necessary to check the theory by a quantitative test, and this onerous task was undertaken by Dr. W. A. K. Christie, with the assistance of M. Vinayak Rao, of the Geological Survey of India, during the hot weather of 1908. After some months of preliminary experiments with artificial winds to ascertain the best method of collecting samples and of determining the limits of experimental error, a laboratory was built in the desert, where anemometer records, temperatures, and barometic pressures were taken at regular and frequent intervals, while samples of the wind were collected at different elevations and analysed. As a result of this work, it was found that during four months of the hot dry season of 1908 the amount of wind-borne salt passing a front 300 kilomètres broad and 100 mètres high must have been something of the order of 130,000 tons. As the meteorological records showed that the hot weather of 1908 was a season of unusually weak winds, the figure obtained is probably well below the annual average influx of salt-dust.

Although the results can thus be stated in figures, they refer to one year only, and are, in a sense, still only of qualitative value. There is no doubt, however, that they establish beyond reasonable doubt the theory which had been formulated on wider considerations, both negative and positive, as to the origin of the enormous quantities of salt now accumulated in the Rajputana desert.

It is necessary, naturally, to exercise caution in extending this theory to other desert regions, some of which are, nevertheless, areas of wind inflow during hot dry seasons. It is also significant that rock-salt deposits are frequently associated with formations that can best be accounted for as due to desert conditions, although such phenomena would be characteristic also of

[1] *Mem. Geol. Surv. Ind.*, vol. xxxv., p. 42, 1902.

areas where, as in the case of the Kara Boghaz of the Caspian, arms of the sea are partly cut off and subjected to desiccation.

Although it is dangerous to generalise from this single instance of Rajputana, in spite of its striking and conclusive character, the observations made in that region are quoted as an instance of an attempt to check by definite quantitative tests general mental impressions of geological dynamics in desert regions. The object of this communication is mainly to urge the further institution, where practicable, of such tests of current theories regarding the physiographic phenomena of arid lands.

Professor W. M. Davis: My interest in the subject proposed for our discussion comes from an endeavour to systematise the study of land forms, so that a well-trained explorer shall be aided in making accurate and complete observations of the ground, and in preparing afterwards for readers as expert as himself a complete and intelligible record of his observations. It would be comparatively easy to reduce such a description to simpler or shorter form for more elementary or more popular use; but it would be impossible to expand a short elementary account intended for beginners, or a popular account intended for general readers, into a detailed monograph intended for experts. The advancement of geographical science will therefore be best promoted by striving to develop a mature thoroughgoing method for the observation and description of all kinds of land forms, including those of deserts.

Much assistance has been given to the study of land forms in general by working out their evolution as dependent (1) on their structure, (2) on the erosional process that works upon them, and (3) on the stages which the forms produced by the work of process on structure pass through, from the initial stage introduced by the movement of a land mass into a new attitude, to the ultimate stage when the process concerned has done all its work.

If we classify what has already been accomplished in this direction with respect to the erosional processes involved, it appears that the theoretical sequence of changes determined by the action of ordinary or normal processes on various structures has been worked out with encouraging success, and verified by confrontation with many examples of actual forms. The explanatory method of describing land forms, based on this theoretical sequence, is now employed by a number of geographers. The same is true of marine erosional processes and of solutional processes. It is less true of glacial processes, though much good progress has been made in that division of the general subject.

With regard to arid processes, theory has outstripped observation; hence the observational study of deserts is much to be desired as a means of testing, correcting, and extending the theory of arid erosion. The difficulty with the descriptions of desert forms hitherto published is that they are so largely empirical and so incomplete that it is impossible to translate them into the phrases of rational or explanatory physiography. Hence what we now need is, the exploration of deserts by trained students, well informed regarding modern physiographic theories.

Let me illustrate this by a special case. The theory of the evolution of desert forms includes a stage in which a lower basin is about to capture the centripetal wash of a neighbouring higher basin; and another stage in which such a capture has recently taken place. The significant characteristics of each of these two stages, as well as of many earlier and later stages, have been defined with sufficient detail to make their recognition easy, provided that the observer is familiar with them; but it would be as unlikely that an observer untrained in physiography would see and describe the essential features of these stages of desert forms as that an observer untrained in botany would see and describe the essential features of plant forms. If one looks through various accounts of desert exploration, it is usually impossible to determine whether actual examples of imminent or of recent basin captures—or of any other special features of desert evolution—actually occur.

The most helpful suggestion that I can offer in this connection is that the effort should be made to refer every element of desert topography first to its proper place with respect to the surrounding contemporary elements in the general working of the processes of desert erosion, and, second, to its proper

succession of earlier and later forms between which it stands; when the elements of a desert landscape are thus seen to be related to many other elements, all systematically disposed in time and place, their observation and their description are greatly facilitated.

The equipment of an explorer of deserts with a good knowledge of the theory of desert evolution is therefore, as I see it, about as important as his equipment with good horses or camels, if it be desired that he should come back from his work with a critical record of what he has seen.

Professor J. W. Gregory remarked that though Scott and R. L. Stevenson used the term desert in its old sense for any uninhabited land, at present the word is restricted to lands uninhabited owing to their arid climate. No numerical limit of desert can be given; and, as Walther has stated, desert cannot be absolutely defined on biological, morphological, or climatic grounds. The cause of desert is not only climatic; geological and geographical structure are both also influential; countries of permeable or friable rocks, and existing as a plateau with an easy drainage to the adjacent lowlands, are easily rendered desert. The climatic influence depends more on the complex conditions which govern the utilisation of the rain and not on its total amount. Proximity to the sea is consistent with the development of desert conditions.

Desert is often more easily utilised than at first appears possible; since the soils often contain such rich accumulations of plant foods that the land is very fertile when watered. Australian soils often need the addition of phosphate, since they contain less phosphorus than the amount held by some authorities to be necessary for profitable cultivation.

He thought that the only explanation of the low phosphorus content in Australian soils and the absence of the usual enrichment of phosphorus in the soil as compared with the subsoil is that proposed by Professor Cherry, who attributes these facts to the rarity of mammals in Australia. In some cases in Australia the poverty of phosphate has been more influential than the aridity in developing desert conditions.

Professor A. Penck: Deserts are regions of the globe which are not only dry but are characterised also by the want of vegetation. Taking such a definition, Australia has only very few deserts; most of what is called Australian desert, indeed, has scrub, even timber. The surface forms of the deserts are more closely controlled by water than by wind. The latter heaps up the dunes, but its erosive action is rather insignificant in comparison with waterwork exercised after rare local rain-showers. Besides this, the surface of many parts of our deserts has been shaped by water before the desert conditions came in. But there are deserts which have been deserts for a very long period. There has been since the end of the Tertiary period a repeated shifting of the climatic belts of the earth, which can be observed especially at the equatorial and polar border of the desert belts, but from the central parts the belt was not shifted away.

Mr. Griffith Taylor: The arid region which I know best is situated in 78° South latitude, but I propose also to discuss the central arid region in Australia.

In Antarctica are many features which closely resemble those described from the desert. Angular breccias are being formed abundantly along the facets of all the glacier valleys in 78° S. Dreikanter are numerous. Striæ are almost absent over miles and miles of moraine. The difficulty of determining the origin of such deposits in fossil condition is obvious.

Professor Gregory has always taken an optimistic view of our own arid region, perhaps I am less sanguine. It behoves us thoroughly to realise the greatness of the problem seeing that approximately one million square miles has less than 10 inches of rainfall. Our visitors who have just seen the region in Western Australia have only penetrated the southern fringe. Moreover, 10 inches of rain in the south mean infinitely more than in the north where evaporation is so

determine if there be a distinct difference such as Goyder demonstrated in so masterly a manner as a safe wheat line (near 13 inches) in South Australia. Only by such necessary research can we really gain adequate knowledge of the potentialities of Australia.

Mr. E. J. Andrews: The observations of the writer in lands of sub-arid, or arid, character have been made only in Eastern Australia and in Arizona, Nevada, and California in the United States. In these regions the surface forms testify to the dominating influence of stream action and to the utterly subordinate action of the wind in sculpturing the lands. To appreciate the part taken in the actual sculpture of desert lands by wind action alone, it is necessary to recognise the fact that ordinary water streams produce peculiar forms, and that these forms are not the result of the stream activity during normal periods, but only during periods of great floods acting perhaps once in a decade. Such forms, however, are continuously mistaken for those due to wind action, by various observers, and from interpretations such as these the action of the wind as an eroding agent is magnified unduly.

The thalwegs of the Australian and American valleys commence in well-marked divides, and their slopes thence decrease continuously towards base-level. Tributary thalwegs also enter the main valleys at accordant slopes. The bases of these valleys are occupied by pebbles and boulders, while these again are covered with deposits of clay and sand. Moreover, certain plants characteristic of fairly humid conditions elsewhere occur sporadically in oases in Eastern Australia within sub-arid regions, and this evidence taken as a whole indicates a very recent decrease in the amount of precipitation in drier Eastern Australia. Such action has only slightly modified the general appearance of the land forms developed in a previous cycle, save for killing off much of the vegetation of that previous cycle.

Mr. A. L. Du Toit referred to the dry region of German South-West Africa and the Kalahari. In the coastal sandy wastes, though wind etching is conspicuous, no hollows due to the action of the wind are to be found. Inland, hollows called 'pans,' often saline and usually periodically filled, occur sunk below the general surface, and must have been produced by wind erosion. All kinds of pans, from 'living' to 'fossil,' can be found, just as in the case of the sand dunes.

Mr. A. T. Kenyon: The general trend of the speakers' remarks showed that desert or rather arid occurrences were distinctly local, and no generalisation could now be made. The area in Victoria which might be called arid was only so on account of its rainfall, which averaged about 14 inches. Its vegetation was abundant. No definition of desert had yet been made which was really applicable to it.

The reference to Goyder's rainfall line, which was undoubtedly fixed by the occurrences of salsolaceous vegetation, needed some comment. Salt bushes grow on soils suitable to their demands, and rainfall was only a small factor. The southern limits of *Heterodendron oleaifolium*, which agreed with the line of distinct change from the *Buloke* or hybrid type of *Belar* to its typical form, was a more reliable guide; but profitable agriculture had long passed even that limit.

In regard to Victorian Mallee saline occurrences, these undoubtedly were confined to the lowest trough of a synclinorium, and were the exposed surfaces of underground sheets of salt water. This has been proved by a number of bores. They were also accompanied by beds or mounds of gypsum or *copi* as locally named, and lime carbonate. The artesian waters of the underlying marine beds held the same salts in similar proportions.

In general, lakes or swamps, the terminals of water-courses, were fresh, as were also the swamps or lakes corresponding with Dr. Du Toit's pans, and dependent upon local catchment only for their water supply.

In regard to sand ridges these æolian drifts occur all over Victoria in the western and north-eastern portions, which are the most fertile parts of the State. In the Mallee the size and arrangement of the ridges seem to be

particularly influenced by the character of the soil. In the better parts of the Mallee, with stiff clayey soil, they are with difficulty describable. In the more sandy and medium agricultural soils they had a marked parallelism and were of moderate size, but in the sand-hill and heath country (locally known as desert) this parallelism was of a general character only, and the sand-hills or ridges were known as 'jumble.' Some of these hills were as much as two hundred feet in height above the surrounding surface. None could be described as 'dune morte,' neither was it at all evident that they were fixed or fossil dunes, the more likely theory being that they were still being formed by action of single sand-grain movements. Owing to the weather being a succession of cyclones there was no prevailing direction of wind, though the westerly course of these depressions might be taken as generally governing the main sweep of the winds. Taking this as a general direction the ridges run with it and not at right angles.

The east winds seldom occur, but frequently are of great force; they never shift any sand. All other winds, particularly the north-west, west, and south-west winds, shift sand, but only in places where man has removed the natural protection of herbage either by clearing or cultivation or by fires occurring in times of drought. None of the sand shifted is air-borne, but is rolled along the surface of the ground. At Wirrengren Plain, the termination of the outlet creek or the final flow of the Wimmera River, there were in the drought of 1902 after a bush-fire had swept over the sand-hills on the west some 500,000,000 cubic yards of sand, or at the rate of 50,000,000 per mile in length drifted on to the plains. In the succeeding year, one of good rainfall, the herbage again fixed the sand-hills, while the sand on the plain gradually drifted eastwards until four years ago the plain was again in its original condition. Similarly the outlet creek itself in its course of fifty miles through white sand-hills retained its original section; the sand blown in at certain exceptional seasons gradually drifting out to the east.

Supplementing Professor Gregory's remarks on the phosphoric acid contents of Victorian soil, it should be pointed out that the Mallee soil contained only about twenty parts per 100,000 or one-half of the average Victorian soil. This refers to the agricultural part of the Mallee, whereas in the sand-hill and heath country the amount of phosphoric acid was hardly ascertainable by chemical methods, and it was practically non-existent.

The methods of farming which led to the successful occupation of all this country originated in South Australia over forty years ago, where the recently christened 'dry farming' had resulted in the prosperous and productive settlement of land with under 10 inches annual rainfall. The cost of production of wheat was under 1*s*. 6*d*. per bushel, and there were at least a hundred million acres suitable for its cultivation.

Dr. W. F. Hume: The characters of an arid land cannot be separated from its past history, and in Egypt five physiographic features of first importance have to be considered. These are:—

1. A belt of deep depressions in the extreme west, the famous Oases.
2. The broad waterless expanse of the Western or Libyan Desert, to the west of the Nile, and the corresponding limestone plateau region (the Maaza Limestone Plateau) to the east of the river.
3. The Nile Valley with its Delta.
4. The Wilderness of the Red Sea Hills and Sinai with its rugged mountains and tortuous valleys.
5. The Red Sea and its narrow prolongations, the Gulfs of Suez and Akaba, together with the coastal plains.

Each of these divisions requires separate treatment. The paper gives a rapid sketch of the geological history of Egypt as known to us at present, the formation of the ancient core of Pre-Cambrian or Palæozoic sediments, volcanic rocks with invasion by granitic magmas, the brief Carboniferous marine advance, and later the much more important Jurassic-Cretaceous transgression, which practically affected almost the whole of Egypt, giving rise to the Nubian Sandstone and the important phosphate-bearing Cretaceous series. The Eocene strata which form the major portion of Central Egypt are probably formed, at the base, of

re-made Cretaceous material, and only in their upper portions show marked evidence that the underlying sandstones and igneous rocks are undergoing erosion.

The re-arranging of Cretaceous strata eroded during Eocene times is regarded by the writer as explaining the great difficulty experienced in drawing a lithological line of unconformity between the beds of these respective periods, though the faunal differences indicate the great break between them.

Fringing the pre-Eocene and Eocene areas of Egypt are a series of Miocene and more recent formations which are of great interest both from tectonic and economic points of view.

In considering the separate physiographic features it is pointed out :—

(A) In the formation of the Oases it is necessary to consider the denudation of the area by marine erosion while rising from the sea and the effects of former more humid climatic conditions. Where the Nubian Sandstone or other soft beds have been exposed, as Beadnell has pointed out, the Oases depression without outlet is produced by wearing through wind-blown sand.

(B) The Great Plains of the Libyan Desert are regions of low dip, of meagre rainfall, and thus wind is the dominant factor. A sandy region to the north supplies the sand necessary for erosion. The character of the desert surface depends on the nature of the geological strata present. The undulating gravel plateaux, or *serir*, the limestone expanse, the 'melon' country, and the fossil floors are various forms in which the desert presents itself, the main feature being the removal of all particles capable of being transported by wind. These are deposited as sand falls in the wind shadows of the Nile Valley scarp or other depressions. The sand-dunes which are locally developed are in sharp contrast to the main desert, these probably depending on three main factors, the existence of sandy deposits, determining their source of origin, the usual direction of the wind their trend, and the relief of the ground their position.

The Maaza Limestone Region is similar to the Libyan Desert, but has a greater rainfall. It thus presents a fine example of the effects when rain acts during short periods on rock surfaces affected by temperature variations. Deep ravines, remarkable water-holes, caverns, natural bridges, and surface coloration films due to the trickling down of ferruginous solutions over cliff walls are among the prevailing features in the southern part of this area.

(C) The present course of the Nile Valley appears to depend on three factors: (*a*) The formation of the syncline, the axis of which it partly follows; (*b*) the erosion of the softer strata along their outcrops determining the present north-south trend of the major courses of the river; and (*c*) the possible effect of the rotation of the earth (Van Baer's law), the stream tending to hug its eastern bank. Attention is called to the region of exceptional erosion where heavy masses of Eocene limestone rest on and have slipped over the subjacent soft Cretaceous marls and slates. These slips must have been connected with greater rainfall and earth-movement as widespread terraces extend in front of the main cliff and rise to some 110 mètres above the present river level. The triple terracing of the Nile is briefly considered.

(D) The Mountain Region of the Eastern Desert is essentially an anticlinal area, where tension is in excess of compression. The differential movements are considerable, minor folds play a conspicuous part, and great fractures determine earth-features of considerable magnitude. The result is that the masses of granite and metamorphic rocks hidden beneath the surface in Central Egypt are here exposed by denudation, forming the Red Sea Hills and Sinai mountains.

The different geological formations give rise to very varied surface features. Attention is called to the importance of rain as a sculpturing agent. The soft Nubian sandstone is easily eroded both by wind-borne sand and by water, giving rise to conspicuous depressions. In the granitic areas temperature variation breaks up the solid rock, huge domes are produced by flaking off of concentric shells. Dykes give rise to marked differences in surface outline, the harder quartz-porphyries determining the form and general trend of many of the mountain summits, while the softer diabases, being easily eroded, give rise to gullies seaming the precipitous sides of the granitic hills. The general character of the country where schists and volcanic rocks are present is also described.

(E) In the Gulf of Suez area another factor has come into play. Here sea-arms project far inland between land-surfaces subject to desert conditions, and their waters become centres of far-reaching chemical activity. Thus coral reefs are changed to dolomites, sea-shells of carbonate of lime to gypsum, hydrocarbons are in quantities of economic importance, and mineralised areas of lead and zinc ores, of manganese oxide, of iron pyrites, and of sulphur are present in the young Tertiary beds which fill these Red Sea depressions. From Suez to beyond Halaib, that is, throughout the length of Egypt, gypsum forms a conspicuous fringe between the ancient hills and the sea, generally dipping gently seaward on the borders of the Red Sea itself. Further north, in the Gulf of Suez area, the conditions are more complicated. Dyapir, or piercing folds such as have been described by Professor Mrazec in Rumania, are of common occurrence, and there is remarkable interplay between the hard and soft members of the folded series.

The surface structure of an arid land is not only the direct reflex of its geological structure, but also of former climatic change. Many factors in Egypt point to great rainfall in the past, such as gravels of igneous material in the Nile Valley far from their source of origin, masses of travertine in the Oases, the varying terraces of the Nile Valley itself, the evidence of expansive lakes at Kom Ombo, &c.

Though the main features of a desert land depend on the geological structure and in part on past climatic conditions, there are characteristics which are typical of all arid regions. These are far removed from the great marine areas and from the zone of rainfall dependent upon solar activity in lands beneath the tropics.

These typical desert features have already been referred to, and include :—

1. The sweeping of all fine material from the surfaces of the plains by the action of the wind, and formation of plateau summits.
2. Intense scouring of these surfaces by wind-driven sand.
3. The breaking up of the most solid rocks by temperature variation.
4. The formation of sand-dunes behind obstructions or where the relief of the ground favours their development.
5. The formation of mushroom-shaped pillars, or standing out of harder materials on bases undercut by the sand.
6. The formation of sand-worn pebbles of typical angular outlines, the well-known Dreikante.
7. Vermicular markings on limestones, due it may be to etching during the movement of evaporating saline solutions.
8. Formation of desert-crusts by leaching out of the soluble materials contained in the rocks, with evaporation at the surface, resulting in deposition of the oxides of iron and manganese. Mr. Lucas, Director of the Survey Department Laboratory, has made a special study of these desert and river films, the latter probably only differing from desert ones in degree.
9. Flaking off of surfaces in the surface zone affected by temperature variation. Also fracture due to the same cause. Fragments of porphyry, limestone, &c., are often split into a series of parallel flakes standing vertically, their original connection to one another being clearly indicated by their close juxtaposition.

In the half-desert where rain, though brief, is intensely active while it lasts, a series of interesting phenomena are presented: deep cañon-like valleys, boulder-strewn gullies, saw-back ridges, parallel-dyke country, saline marshes, dry waterfalls or steep precipices in the valley-floors, and great talus-slopes.

Mr. Ferrar, in reply to a question asked by Professor A. P. Coleman, explained that the slope of the wadis from the watershed towards the Nile was about 1 to 1,000 and towards the Red Sea 1 to 200 or 1 to 300, but that the slope was of little moment, owing to the sudden rush of storm-water from its gathering-ground on the bare mountain-sides. He had not actually observed scratchings on rocks because they had not been sought, but he had seen great heaps of boulders in unstable equilibrium, which, if overbalanced, could not avoid being mutually scratched. He was aware that the scratches on some of

the blocks of the so-called Permian breccias were merely eroded veins or filaments of mineral which could be seen inside the rocks if they were broken across, and that there was little similarity between the wadi-breccias of Egypt and the moraine-breccias of Antarctica. With regard to Mr. Du Toit's remarks on salt-pans he agreed that dunes to leeward pointed to erosion and that therefore we should expect to find a great accumulation of dunes to leeward of the Egyptian Oases: such accumulations are wanting. Professor Penck's observations on the poleward movements of deserts could be interpreted in two ways: *either the in-draught of air towards the equator carried sand from temperate zones on to the sub-desert areas, thus rendering them essentially deserts and causing a poleward migration of their edges*; or, and this has an important bearing on the size of Polar ice-caps, our earthly boiler and condensers (the Tropics and the Poles) are losing in efficiency, and consequently both regions are becoming drier. The Wastwater Screes were a known example of breccias forming in a region whose climate is hardly desertic.

Mr. Ferrar said he was well aware that the Nubian Sandstone was exposed in the floors of the oases and that vast quantities of rock-material had been removed, nevertheless he still found himself in Professor Walther's position of ten years ago, and, after seeing wind-driven sand tending to fill the oases-depressions and not excavate them, did not think the wind-erosion theory consistent nor a sufficient explanation of their origin. He holds the view that wind-erosion tends to remove all rugosities and that the ultimate physiography of an arid land-surface is a smooth level plain.

With regard to Sir Thomas Holland's criticism as to quantitative results, Mr. Ferrar suggested that data, similar to that collected in Rajputana by the Indian Geological Survey, could be obtained by measuring the quantity of sand brought in to the oases at their northern ends and the quantity carried out southwards. Any difference would show the rate of erosion or deposition, according to sign.

In concluding his remarks Mr. Ferrar thanked his audience for their interest in and their appreciation shown towards his papers.

After remarks by Mr. D. M. S. WATSON, the discussion closed.

WEDNESDAY, AUGUST 19.

The following Papers were read:—

1. *On the Age and Sequence of the Tertiary Strata of South-Eastern Australia.* *By* FREDERICK CHAPMAN, *A.L.S.*

Divisions of the Kainozoic.

It is convenient to divide the Australian Tertiary system into four or five main series, using the local terms suggested by Hall and Pritchard. In ascending order, these, according to the writer, are:—

1, Balcombian. 2, Janjukian. 3, Kalimnan. 4, Werrikooian. Above these comes the Pleistocene series, referred by many geologists elsewhere to a separate system, the Quaternary.

These divisions, broadly speaking, correspond with:—

1, Oligocene. 2, Miocene. 3, Lower Pliocene. 4, Upper Pliocene.

The present writer maintains that, giving due allowance to time discrepancies in regard to the factor of distribution of life-forms over wide areas, guide fossils are probably as important in dividing and allocating these beds to the well-known horizons of the northern hemisphere as are percentages of living forms in these fossil deposits. The percentage method can only be used with safety as an approximate guide to age, seeing the difficulty of obtaining an agreement amongst zoologists as to what constitutes a species.

The above series of European divisions correlated with the Australian corresponds almost exactly with McCoy's original determinations, augmented by

observations on faunas and stratigraphic relationship of the beds made by the writer during twelve years' attention to this subject.

Sequence of the Beds.

With regard to the sequence, some Victorian authors hold the opinion that the Janjukian series is older than the Balcombian; but the confusion seems to have arisen from the occurrence of a large number of persistent species, especially of mollusca, passing up from the argillaceous Balcombian into the Janjukian clay series. Where faunistic and stratigraphic relationships were both doubtful the term Barwonian was suggested, which included both Balcombian and Janjukian. If, however, we regard the scope of the Janjukian in its broad sense as embracing all phases of sedimentation, of one long time series, the term Barwonian is no longer needed, its members being included in the term Janjukian. The sequence of the beds 1, 2, and 3 as given here has lately been established by the author from evidence obtained in cliff-sections at Muddy Creek near Hamilton, and in the bores put down in the Mallee and at Sorrento.

Other authors since McCoy agreed as to the present sequence, but differed in regard to the age of the oldest beds, which they held to belong to the Eocene, making the succeeding beds correspondingly older.

Guide Fossils.

The various members of the Australian Kainozoic system have been referred by the writer to the horizons given above, chiefly through a study of the cetacean types, the fish remains, the mollusca, the polyzoa, the ostracoda, and the foraminifera. In the oldest beds (Balcombian) a predominant fossil is *Amphistegina*, long mistaken for *Nummulites variolaria*, the latter genus in reality being absent. In the limestone phase of the succeeding Janjukian beds the Miocene type of toothed whale, *Parasqualodon*, occasionally occurs; in the marls the Miocene genus *Spirulirostra*; whilst the Burdigalian forms of *Lepidocyclina* are abundant in the polyzoal series of the Janjukian. In the Kalimnan series cetacea known elsewhere in the Pliocene Crag (Diestian and Astian) of Antwerp and England, as *Scaldicetus* and the ziphioid whales, are characteristic fossils. The above interpretation of the Australian Tertiary sediments agrees also with the data acquired by Australian physiographists, and is that generally accepted for New Zealand and Patagonia.

Terrestrial Series.

The terrestrial Tertiary deposits, so far as they are known, are assi[gned to the] various horizons as follows:—

Balcombian.—Leaf-beds of Mornington and the brown coal of the [...] Coal-shaft.

Janjukian.—Leaf-beds of Sentinel Rock (Cape Otway), Ha[...] Bacchus Marsh, Pitfield Plains, Narracan, Dargo High Plains [...] Deep Leads: in Victoria. Leaf-beds of Dalton, Gunning, and [...] in New South Wales. Leaf-beds of Lake Frome, &c.: in Sou[th Australia].

Kalimnan.—Newer Deep Leads, Haddon, Victoria. Also o[...] South Wales.

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2. *The Age and Sequence of the Victorian Tertiari[es].*
By T. S. HALL, *M.A., D.Sc.*

The chief difficulty that meets one in attempting to decide the [...] marine Tertiaries of Southern Australia is their wealth in well-preserv[ed fossils]. From the oldest series, the Barwonian, which includes the close[ly related] Janjukian and Balcombian, about 1,800 species have been described. [This] includes over 600 mollusca, some 500 polyzoa, and about 40 brachiopoda, 50 echinoids, 80 corals, and a large number of foraminifera. The Kalimnan yields about 260 described species, mainly mollusca, while the Werrikooian affords close upon 200 species of described mollusca. It may safely be said that when the fauna of the Barwonian, at any rate, is fully described the total will be doubled, for, taking the mollusca, the small forms, which are extremely

abundant, have not been touched, and a large number of new species in almost all groups are known, but remain undiagnosed.

The basis of classification is in dispute. In spite of all objections I adhere to the Lyellian percentage method as yielding the best results. Another method has been adopted by Ortmann in dealing with the Patagonian Tertiaries. It consists in comparing each species with species of known age in the northern hemisphere, deciding which is the nearest 'ally' or 'representative,' and referring the southern formations to those northern ones which yield the greatest number of 'relationships.' It passes by as of no importance all the southern forms. Harris suggests using phylogeny *pari passu* with the Lyellian method.

The objection urged against the Lyellian method is that the personal equation enters too largely into it, and we do not know what a species is. H. von Ihering has discussed Ortmann's method fully, and objects to it. To my mind the personal equation is as prominent in it as in the Lyellian, and it demands an amount of knowledge of the Tertiary faunas of the world that no one can possibly have at first hand, and enormous collections, quantities of each species, that no museum is likely to contain. As regards phylogeny, we cannot use it till we know the sequence.

Confining ourselves to the mollusca, we find Tate recognising about a dozen recent species in the Barwonian. Later authors have more or less definitely recognised about half a dozen more. As we have over 800 named species in this series of beds, we may double the number of recent ones without seriously affecting the result.

Assuming that the Barwonian is Eocene, for some age has to be assumed, I have elsewhere discussed most of the genera that transgress.[1] Some pass up from Mesozoic times, others are extensions back from younger horizons in the north, or from recent seas. Besides this the absence of many modern genera must be insisted on. It is customary for those who hold that the Barwonian is younger than Eocene to label all the old genera 'survivals.' This hardly settles the question. Leaving the land fauna on one side, there are some undoubted survivals in the Indo-Pacific, but it may be asked, Did nothing originate in the southern seas and slowly migrate northwards? The real place of origin and age of the transgressing genera cannot be settled off-hand by northern standards.

The Barwonian is divided into Balcombian and Janjukian, but their relation-
...en vigorously discussed. By far the greater part of the fauna is
...e two. Passing by the discussions between Professor Ralph Tate
...ennant on the one side, and Dr. G. B. Pritchard and myself on the
The fol... ended, as such discussions frequently do, in a series of flat contra-
... facts, we may consider Mr. F. Chapman's position.
1. On th... man asserts that the Batesford limestone is typical Janjukian, and
... conclude that all the polyzoal limestones, and there are many, are
...an. He argues on the same data that the Janjukian is the younger
...ate, Dennant, Pritchard, and myself, however much we differed on
It i... ints, agreed that the age of the limestones must be decided by reference
main... rich fauna of the clays. Mr. Chapman makes no reference to an inter-
ing... d clay bed in the Batesford limestone from which Dr. Pritchard and myself
...cted forty-five species, mainly mollusca. Of these only one is confined to the
co... Janjukian locality, while twelve have never been found there, but are
sy... ed to typical Balcombian beds. The rest are common to both series.
...mestone, then, as we asserted, is Balcombian and not Janjukian. More-
...e showed, by a careful examination of the area, that the limestone passed
I... clays which are typically Balcombian, and can be traced to Orphanage
T... ly a couple of miles away. M'Coy grouped the Orphanage Hill beds
in re... hose of Mornington, that is, with the type Balcombian section. Tate, Dennant, Pritchard, and myself agree with the grouping, and Mr. Chapman still labels the Orphanage Hill fossils Balcombian in the National Museum. If, as Mr. Chapman asserts, the Batesford limestone is Janjukian, then the Balcombian is the younger and not the older member, as he asserts. The stratigraphical facts are unimpeachable.

The Mount Gambier limestones must, as the contained mollusca show, be

[1] Rep. Aust. Assoc. Adv. Science, Hobart, 1902; Pres. Addr. Sec. C.

associated with the Balcombian of Muddy Creek. The polyzoal limestone of Muddy Creek rests on quartz porphyry, and is the basal member of the series. It has been traced by Dr. Pritchard and myself passing under the more loosely compacted beds of the district, and is inseparable from them.

The polyzoal limestones of Jan Juc, Waurn Ponds, and a few other places are Janjukian, and the evidence rests on the mollusca, but this has no bearing on Mr. Chapman's main contention.

The relative age of the Janjukian and Balcombian is a difficult question. M'Coy, Tate and Dennant, and Chapman consider the Janjukian the younger. Dr. Pritchard and myself consider the reverse to be the case.

As regards the other formations, it may be briefly said that the estimate of their age depends on that of the Barwonian. If this be Eocene, they are Miocene and Pliocene respectively; if not, they must be placed higher in the scale.

3. *On the Age and Sequence of the Victorian Tertiaries.* *By* G. B. Pritchard, *D.Sc.*

Tertiary geology in South-Eastern Australia has been fruitful of much difference of opinion, partly on account of lithological variations associated with palæontological variations which have not always received due weight, the difficulty of correlating disconnected outcrops, bores, and shafts, and the degree of antiquity and relative age of the various horizons represented. The various changes in this work have no doubt been a stimulation to some, but to many it has been, and still is, very confusing.

It happens that marine deposits are well developed, many showing a remarkable wealth of fossils, and these have attracted more attention than their terrestrial and volcanic associates. Amongst the marine fossils, mollusca are usually very striking, and it is only natural to compare these with Australian living forms. In this way a succession can be determined for the fossil faunas as at present known, showing further and further removes from the living.

(*a*) Werrikooian.—The type locality is at Limestone Creek, a small tributary of the Glenelg River, in the parish of Werrikoo, South-Western Victoria. These beds bear a molluscan fauna strictly comparable with living forms along the southern coast except for the occurrence of a few species at present unknown amongst the living fauna.

(*b*) Kalimnan.—The type locality is near the township of Kalimna, Gippsland Lakes, Eastern Victoria. The fauna of these beds is also comparable in general facies with the recent, in the proportion of bivalves to univalves, and relative abundance of representatives of other groups. It includes extinct genera, as well as a very high proportion of extinct species.

(*c*) Balcombian.—The type locality is at Balcombe's Bay, east shore of Port Phillip. The fauna of these beds is richer and more varied than the existing Southern fauna; its general facies is more comparable with Northern Australian forms. In the present state of our knowledge it contains rather more than two per cent. of extinct genera, and even allowing a wide margin for differences of opinion the living species would barely represent two per cent.

(*d*) Janjukian.—Coastal sections on Bass Strait, parish of Jan Juc, south of Geelong. The fauna from these beds appears to be furthest removed from the living, based on a review of the genera which shows between five and six per cent. extinct, whilst the species only show about one per cent. living forms.

When the typical fossils are not obtainable it is not easy to state whether a rock series is Balcombian or Janjukian. To meet this difficulty the wider term Barwonian has been given, as both these horizons are well developed in the Barwon Basin.

Stratigraphical evidence also exists in confirmation of the above sequence in the Moorabool Valley, in the coastal sections from Port Campbell to Cats' Reef and elsewhere.

4. *On the Age of the Lower Tertiary Marine Rocks of Australia.* *By* R. Bullen Newton.

The author referred briefly to the valuable palæontological work on the Australian Tertiaries carried out by such prominent authors as M'Coy, Ralph Tate, Dennant, Hall, Pritchard, &c., the majority of whom favoured an Eocene Age for the Lower Tertiary deposits of Australia. The late G. F. Harris doubted the existence of such a formation, whilst M. Cossmann could see no relationships among the Lower Tertiary Opisthobranchs from Australia with Eocene forms from Europe.

Mr. F. Chapman, palæontologist of the Melbourne Museum, has studied this subject, and proves very conclusively that those beds hitherto regarded as Eocene belong to the Miocene period—a view which the author fully supports. Mr. Chapman's work on the Batesford limestone is important in this connection, because of its containing *Lepidocyclina*, *Amphistegina*, and *Lithothamnium*—all of which characterise the Miocene beds of Europe, Java, Sumatra, Borneo, Formosa, &c.; the absence of nummulites in this limestone is against its age being either Eocene or Oligocene. These same limestones have also yielded Mollusca and Brachiopoda, as well as *Carcharodon megalodon*, which has its origin in Miocene rocks. The author was of opinion that the Lower Tertiary faunas of Australia presented in some cases a recent facies, in others a Miocene facies with relationships to both European and South American species of that period. Among shells showing a resemblance to those of present-day seas, he mentioned *Cassis contusus*, *Siphonalia spatiosa*, *Typhis laciniatus*, all Tate's species, and mostly from the Muddy Creek deposits; and many more species might be quoted exhibiting a more or less recent appearance. Among fossil forms more particularly referred to was the *Aturia aturi* var. *australis*, which has been recognised as coming from the Eocene of Australia. Although given a varietal name, this Cephalopod is not to be separated from the Miocene species of Europe known as *Aturia aturi*, and with this statement Mr. Crick, of the British Museum, thoroughly agrees. The species is found in many of the Australian deposits, as also in the Table Cape beds of Tasmania, the Oamaru beds of New Zealand, the Navidad beds of Chili, South America, as also in the European Miocene. The more or less pointed rostrum of *Spirulirostra curta* illustrates an affinity with Miocene forms rather than with Eocene, which are more obtuse.

The large *Cypræas* described by M'Coy as Oligocene should more probably be regarded as Miocene, since they come from the Gellibrand River Beds, Muddy Creek deposits. &c., which also contain the *Aturia aturi*, before mentioned. The Brachiopods of the Lower Tertiary deposits of Australia show a somewhat recent facies, a striking form being *Magellania garibaldiana*—a species occurring in the Mount Gambier Beds in association with the *Aturia aturi*.

Even before Mr. Chapman pointed out the Miocene characters of the Lower Tertiary deposits of Australia, Dr. Ortmann, of the United States, had published in 1902 his important monograph on the Tertiary deposits of Patagonia, in which he compared the faunas of that continent with those of Australia. His researches were against the presence of Eocene in the Tertiaries of Australasia, and those beds hitherto recorded as such he identified as Miocene, and contemporaneous with the Pareora beds of New Zealand, Navidad series of Chili, and the Patagonian deposits, all of which showed unmistakable affinities with each other and favoured the view that a former connection existed between South America and Australasia.

The term Oligocene among Australasian marine Tertiaries, the author was inclined to abandon because of the absence of Nummulites, their place being taken by *Amphistegina* and Lepidocycline forms of Foraminifera. Such rocks he would regard as Miocene. This would apply to the Balcombian and Janjukian beds of Mornington &c. and the older deposits of Muddy Creek and other localities.

5. The Correlation of the Australian Marine Kainozoic Deposits—Evidence of the Echinoids, Bryozoa, and some Vertebrates. By Professor J. W. Gregory, F.R.S.

Correlations of the Kainozoic deposits which extend along southern Australia have been proposed in accordance with two main conclusions. According to the first, these deposits include marine representatives of all the Kainozoic systems from the Eocene to the Pleistocene. According to the alternative explanation, most of the deposits belong to the middle part of the Kainozoic, and include essentially one fauna. When I succeeded M'Coy in Melbourne in 1900 I had to consider this question, and carefully examined the evidence given by the two groups of animals in which I was most interested, the Echinoidea and the Bryozoa, and also compared their evidence with that of some fossil vertebrates. The second correlation seemed the better to agree with the evidence of these groups. The Echinoidea had been regarded as indicating the Eocene age of some of the deposits, for one characteristic fossil had been referred to the genus *Holaster*. This determination had, however, been revised and the fossil referred to a new genus, *Duncaniaster*, whose affinities are with much later echinoids than *Holaster*. The fossil echinoids could all be included in one fauna; some of the most characteristic species, such as *Clypeaster gippslandicus* and *Monostychia australis*, range from the Balcombian to the Kalimnan, and *Lovenia forbesi* has the same variations in the Janjukian and Kalimnan. Some of the rarer species are limited to one locality, but that is probably only due to their scarcity. The characteristic Echinoids indicate one fauna, which is essentially Miocene, though it may have overlapped with the upper Oligocene and lower Pliocene. The evidence of the Echinoids is decidedly in favour of the view that there has been one great marine transgression along the southern coast of Australia, which reached its maximum in the Miocene if it were not confined to that system.

The evidence of the Bryozoa is less definite, but when carefully examined it supports the same conclusions. Many of the genera lived in the Eocene and Cretaceous; but most weight should be given to the most specialised Cheilostomata found in these deposits. Some well-known living species, such as *Retepora beaniana*, *Smittia reticulata*, and *Porella skenei*, are found in the Victorian beds, and they indicate an upper instead of a lower Kainozoic age. The survival of some older Bryozoa is less significant than the first appearance of the highly developed upper Kainozoic species. Macgillivray in his monograph (1895) said that the Victorian Bryozoan fauna included no Eocene members, and that the different horizons represented were not very different in age. With those conclusions I fully concur.

The vertebrate evidence appears to me to support the same determination. The appearance of *Squalodon*, *Scaldicetus*, and *Ziphius*, and of such well-known species of sharks as *Carcharodon megalodon* and *Oxyrhina hastalis*, which range from the lowest to the highest of the main Victorian marine series, is in favour of those beds being not earlier than Miocene. It is true that both species have been recorded from the Eocene of the United States; but these American Atlantic deposits are not an altogether satisfactory basis for correlation; and these species make their first appearance in the standard Kainozoic succession of Europe in the Miocene, and they last on to the Pliocene.

The classification adopted recently by Mr. Chapman seems to me in essential agreement with the evidence of the Echinoids, Bryozoa, and Vertebrates, most of the marine Kainozoic beds of southern Australia belonging to the Janjukian and being of Miocene age.

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6. The Evolution of Victoria during the Kainozoic Period. By D. J. Mahony, M.Sc., F.G.S.

The Kainozoic period in Victoria is characterised by great earth movements accompanied by volcanic action; the present topography is a consequent development.

The central highland area (Palæozoic rocks) extends from the eastern boundary of the State westwards to the Grampians; to the north and south

it is bounded by low-lying plains (Kainozoic strata), which gradually broaden towards the west until they merge into one another. To the south Wilson's Promontory (granite), South Gippsland (Mesozoic), and the Cape Otway district (Mesozoic) rise above the plains. The highland area is essentially a dissected peneplain sinking from some 5,000 feet above sea level in Gippsland to 900 feet at its western extremity; the only Kainozoic rocks upon it are river-gravels, lake-deposits, and volcanics.

The plains (500 feet) are areas of Kainozoic sedimentation with some interbedded and overlying volcanic rocks; the sedimentary series consists of lacustrine or estuarine beds, followed by marine clays (Oligocene), foraminiferal limestones (Miocene), and sandstones (Pliocene). These beds rest upon Palæozoic or Mesozoic rocks.

On the surface of the ancient peneplain, 5,000 feet above sea level, (?) Miocene plant-remains and river-gravels are preserved beneath basalt at Dargo High Plains. This indicates a long pre-Miocene period of quiescence followed by a great uplift. This area has not been submerged during the Kainozoic.

The nature of the Kainozoic series indicates that, outside the highland area, a gradual subsidence of considerable magnitude (Oligocene and Miocene), accompanied by volcanic outbreaks (Miocene), was followed by re-elevation to a maximum of about 900 feet above sea level (Pliocene or post-Pliocene). There is evidence to show that the movements were not uniform in direction, though the net result was depression or elevation. Bass Strait is a recently sunken area in which equilibrium has not yet been established.

The nearly horizontal position of the Kainozoic rocks indicates that the movements were vertical; and there are, moreover, examples of Kainozoic faults in which the differential movement amounts to 900 feet.

The volcanic rocks are basaltic except for sporadic occurrences of alkali rocks in Eastern, Central, and Western Victoria.

The Older Basalts are most abundant to the east of Melbourne. Some remnants occur on the ancient peneplain 3,000 feet above the present streams, but the most extensive areas are at lower levels in South Gippsland. At Flinders the Older Basalt underlies marine Miocene, and has been proved by boring to be over 1,300 feet thick, and to extend from sea level to that depth. In some instances the age can be conclusively proved, but in others the evidence is poor. These basalts are associated with the first great period of earth movements.

The Newer Basalts are most extensively developed in the western district, where their northern boundary is not far from the 500 feet contour; here they overlie marine Kainozoics. Large areas are also found on the plateau west of Kilmore and along its northern flanks. The Newer Basalts are never covered by marine deposits, except recent accumulations near the coast, their surface is little denuded, and many of the cones of loose scoria are almost perfect. It appears that the Newer Basalts mark the close of the last great movement which elevated the marine Kainozoics.

In New South Wales and South Australia earth movements on a grand scale took place during the Kainozoic period, yet volcanic action was comparatively insignificant.

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7. *The Tertiary Brown Coal-beds of Victoria.*
By H. Herman, *B.C.E., M.M.E., F.G.S.*

The brown coal-beds of Victoria are probably the thickest yet recorded in the world. The more extensive areas are the La Trobe Valley, Alberton, Altona, and Lal Lal. Minor beds are widely distributed.

The geological age has not yet been definitely fixed, except at Altona, where a brown coal-seam 140 feet thick underlies marine Oligocene beds. Flows of basalt overlie the brown coal in places, and underlie it in others. The range in age is probably from Oligocene upwards. Seams outcrop at Narracan, Thorpdale, Dean's March, Morwell, and Boolarra.

Where below the surface the seams are prospected by boring. In many bores coal of several hundred feet in thickness is shown; one bore had an aggregate thickness of 781 feet of coal in a depth of 1,010 feet. The overburden is from a few feet to 500 feet deep.

In the Alberton area of about 300 square miles and the La Trobe Valley area of 700 square miles there is probably 30,000,000,000 tons of coal. The approximate area at Altona is 200 square miles, with a probable average thickness of 50 feet of coal. At Lal Lal the coal covers three square miles with an average thickness of 80 feet.

The geological and geographical distribution of the various brown coal-seams is still being ascertained by boring; the bores are being systematically tested for calorific value, gas production, and by-products. A typical analysis of the brown coal, as freshly mined, is:—

	Per cent.
H_2O	53·00
V.H.C.	24·50
F.C.	21·50
Ash	1·00
	100·00

Sulphur	0·7 per cent.
Nitrogen	0·3 per cent.
Calorific value	5,500–6,000 B.T.U.
Evaporation value	4 lb. water
Gas per ton	6,500 cubic feet

Ammonium sulphate per ton (theoretical), 32 lb.

Experimental work has also proved that under proper conditions a firm hard briquette can be produced without the aid of an agglutinant binder. It is suitable also for use in the gas producer, the improvements in which of recent years bid fair to give brown coal an important place in the power fuels of the world at no distant date.

SYDNEY:

FRIDAY, AUGUST 21.

After the President had delivered his Address (see p. 344) the following Papers were read:—

1. *The Geology of New South Wales. By* E. F. PITTMAN.

2. *The Age of the Permo-Carboniferous Glacial Beds. By* DR. A. VAUGHAN.

3. *Report on the Erratic Blocks of the British Isles.* See Reports, p. 111.

4. *Report of the Committee to consider the Preparation of a List of Characteristic Fossils.*—See Reports, p. 111.

5. *Report on the Geology of Ramsey Island, Pembrokeshire.* See Reports, p. 111.

6. *Report on the Old Red Sandstone Rocks of Kiltorcan, Ireland.* See Reports, p. 113.

7. *Report on the Fauna and Flora of the Trias of the Western Midlands.*—See Reports, p. 114.

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8. *Report on the Excavation of Critical Sections in the Lower Palæozoic Rocks of England and Wales.*—See Reports, p. 115.

9. *Report on Geological Photographs.*

10. *Report on the Microscopical and Chemical Composition of the Charnwood Rocks.*

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11. *Report on the further Exploration of the Upper Old Red Sandstone of Dura Den.*—See Reports, p 116.

12. *Report of the Committee to consider the Preparation of a List of Stratigraphical Names.*—See Reports, p. 113.

TUESDAY, AUGUST 25.

Joint Discussion with Sections D, E, and K on Past and Present Relations of Antarctica in their Biological, Geographical, and Geological Aspects.—See p. 409.

The following Papers were then read :—

1. *On the Term Permo-Carboniferous and on the Correlation of that System. By* W. S. Dun *and* Professor T. W. Edgeworth David, C.M.G.

The term Permo-Carboniferous was originally applied to certain formations in Queensland which on stratigraphical evidence were at the time considered to belong to one and the same general system. At the time it was considered that a series of strata at Gympie, which contained an assemblage of fossils of distinct Permian affinities, were stratigraphically below another set of strata known as the Star Beds. The latter contain among other fossils *Phillipsia*, *Lepidodendron australe*, and *Ancimites*, all typical Carboniferous fossils in Australia, and the first mostly of Devonian age. Accordingly these formations were grouped together under the term Permo-Carboniferous, and the name has subsequently been widely used. It has now been proved that, so far as Queensland is concerned, the name has been given in error. The Gympie Beds are stratigraphically above the Star Beds, not below as was originally supposed. Nowhere in Australia or Tasmania has a single trilobite or *Lepidodendron* ever been found in our Carboniferous rocks proper. In the absence of a zoning of these Carboniferous rocks it is impossible to say what exactly are its equivalents in other parts of the world. If it is wholly Lower Carboniferous, as some suppose, there may be some justification for the retention of the term Permo-Carboniferous, but if its fauna and flora ascend to Upper Carboniferous, then it is suggested that there is much to be said in favour of using the term Permian instead. In Russia *Schizodus* occurs in numbers beneath the whole not only of the *Glossopteris* beds, but of the *Gangamopteris*

beds also of the Dwina system. In South America the Lower Rocks of the Santa Catharina system appear to be more Permian than anything else, and the occurrence of the strong swimming reptile Mesosaurus both in the Permo-Carboniferous rocks of South America and of South Africa suggests that the South African Permo-Carboniferous rocks also may be chiefly Permian.

In the correlation of the Australian Permo-Carboniferous formations, special emphasis is laid on the Indian facies of the West Australian Permo-Carboniferous fauna.

2. *The Great Australian Artesian Basin and the Source of its Supply.* By E. F. Pittman.

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3. *The Geological Relations of the Artesian Water-bearing Southern Queensland.* By S. Dunstan.

4. *The Post-Jurassic Geography of Australia. Notes on the Hypothesis of Isostasy.* By E. C. Andrews.

The doctrine of isostasy implies the general correspondence, in weight, of all vertical columns of unit size composing the Earth's crust to a depth known as the *depth of compensation*. This depth is taken at 122 kilomètres below sea level by Hayford.[1]

The excess of height of the unit columns, in continental areas, is considered as being compensated by the excess of crustal density in suboceanic areas. Isostatic compensation is supposed to follow rapidly upon loading and unloading. Examples of such loading are sedimentation and the formation of a continental Ice Sheet, while examples of unloading are erosion and the disappearance of an Ice Sheet. The adjustment is considered to be a gradual, rather than a spasmodic, process. Anomalies of gravity, however, are recorded from many localities, and Gilbert[2] suggests that the explanation of such is to be sought in *nucleal heterogeneity*.

Geography.—East and West Australia form two positive, or buoyant, elements, while the Inland Plains, in the main, represent a negative, or sunken, area. With these three elements should be considered New Zealand, Malaysia, the South Pacific, the Indian, and Southern Oceans.

During Cretaceous time a great plain of erosion appears to have been formed in the positive elements of Australia, while the extensive epicontinental sea of that period was filled with the waste derived from the neighbouring erosion. Subsequently, both the old plain of erosion and the northern portion of the area of sedimentation were elevated to a moderate height and a long period of equilibrium and erosion ensued. This sequence of elevation and of pauses of equilibrium with erosion was repeated until the close of the Kosciusko Period,[3] the pauses between the uplifts becoming less important, but the amount of vertical movement becoming correspondingly emphasised.

At various stages of the process basalts flooded Eastern Australia, especially in areas of older sedimentation. The appearance of the old basalt-covered stream-drifts is suggestive of a temporary subsidence for the plateau areas during the basaltic period.

Strong streams, such as the Shoalhaven and the Hawkesbury, maintained their general courses against the uplifts along their lower portions. Hence it is inferred that the uplifts were effected slowly, nevertheless the periods of equilibrium separating the revivals of elevation were of much longer duration than the uplifts themselves.

[1] Hayford, J. F., 'Figure of the Earth and Isostasy,' *U.S. Coast and Geodetic Survey*, Washington, 1909.

[2] Gilbert, G. K., 'Interpretation of Anomalies of Gravity,' *U.S. Geological Survey*, Washington, 1913.

The researches of Dutton, Hayford, Bowie, Gilbert, and others appear to have placed the doctrine of isostatic compensation upon a firm basis; nevertheless, the operation of the adjustments does not appear, as yet, to be understood, and it is probable that cognisance has not been taken of all the factors.

In the example cited, of the elevation of both the Great Mesozoic peneplain and a great portion of the loaded offshore area, it seems difficult, under the doctrine of continuous compensation, by erosion and sedimentation, to explain, in the first place, how the positive element could remain, for ages, in the one general position of equilibrium, while the offshore area was being loaded; and, in the second place, how the elevatory movement could have received its initial impetus, especially as the effect appears greater than the cause if it be assumed that the Cretaceous sedimentation gave rise to the Tertiary uplifts. On the other hand, the foundering of suboceanic areas in the neighbourhood might be adduced as an explanation, but the evidence is not at all conclusive on this point.

The history of the revivals of elevation during Tertiary time over Eastern Australia indicates crustal adjustment by jumps, and in this case also the increasing amount of vertical movement suggests that the elevations of the plateaus more than compensate for the erosion sustained in these regions during recent geological time.

The extrusion of the basalts is in harmony with the doctrine, but the action appears to have been catastrophic, rather than gradual, in nature.

The sequence of geographical forms cited suggests that sedimentation influenced the formation of plateaus only in a minor degree, but, on the other hand, that stresses accumulated gradually within the zone of compensation, until a belt of weakness, or mobility, was established by means of which the ill-adjusted portions were connected. Upon the arrival of such a stage adjustment ensued with relative rapidity with the production of epeirogenic uplifts and depressions. This neither denies the ability of a load, such as a mass of sediments, or an Ice Cap, to depress the underlying region, nor does it seek to exclude the tendency for an unloaded area to rise; it merely assigns to such agents a subordinate part in the shaping of the greater features of the Earth's crust.

It is probable also that an analysis of a series of gravity measurements which may be taken hereafter in Australasia would reveal the existence therein of gravity anomalies, and it is probable also that the disposition of these would be other than those which might have been inferred from a mere inspection of the topography.

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5. *The Metallogenetic Provinces of Eastern Australia.* *By* C. A. Sussmilch.

6. *New Evidence for Darwin's Theory of Coral Reefs.* *By* Professor W. M. Davis.

7. *The Genesis of the Diamond in New South Wales.* *By* L. A. Cotton.

8. *The Occurrence of Spilitic Lavas in New South Wales.* *By* W. N. Benson.

9. *Structural Features of the Coal-fields of Pennsylvania and their Influence on the Origin of Hard Coal.* *By* Professor E. S. Moore, *M.A., Ph.D.*

There are two main coal-fields in Pennsylvania, the Bituminous and the Anthracite. The latter field comprises an area of approximately 480 square miles situated in the highly folded portion of the Appalachian Province, while the

Section D.—ZOOLOGY.

PRESIDENT OF THE SECTION: Professor Arthur Dendy, D.Sc., F.R.S.

Melbourne.

FRIDAY, AUGUST 14.

The President delivered the following Address:—

Progressive Evolution and the Origin of Species.

The opening years of the present century have witnessed a remarkable development of Biology as an experimental science, a development which, however full of promise it may be for the future, for the time being appears to have resulted in a widespread disturbance of ideas which have themselves only recently succeeded in gaining general acceptance. The theory of organic evolution, plainly enough enunciated at the close of the eighteenth and the beginning of the nineteenth century by Buffon, Lamarck, and Erasmus Darwin, remained unconvincing to the great majority of thinking men until the genius of Charles Darwin not only brought together and presented the evidence in such a manner that it could no longer be ignored, but elaborated a logical explanation of the way in which organic evolution might be supposed to have taken place. Thanks to his labours and those of Alfred Russel Wallace, supported by the powerful influence of such men as Huxley and Hooker, the theory was placed upon a firm foundation, in a position which can never again be assailed with any prospect of success.

This statement is, I believe, entirely justified with regard to the theory of organic evolution itself, but the case is very different when we come to investigate the position of the various subsidiary theories which have been put forward from time to time with regard to what may perhaps be termed the *modus operandi*, the means by which organic evolution has been effected. It is in this field that controversy rages more keenly than ever before. Lamarck told us that evolution was due to the accumulated results of individual effort in response to a changing environment, and also to the direct action of the environment upon the organism. Darwin and Wallace taught us that species originated by the natural selection of favourable variations, and under the influence of Weismann's doctrine of the non-inheritance of acquired characters the theory of natural selection is in danger of becoming crystallised into an inflexible dogma. In recent years De Vries has told us that species arise by sudden mutations, and not by slow successive changes, while one of the most extreme exponents of 'Mendelism,' Professor Lotsy, lately informed us that all species arise by crossing, and seriously suggested that the vertebrate type arose by the crossing of two invertebrates!

This curious and many-sided divergence of opinion amongst expert biologists is undoubtedly largely due to the introduction of experimental methods into biological science. Such methods have proved very fruitful in results which at first sight seem to be mutually contradictory, and each group of workers has built up its own theory mainly on the basis of observations in its own restricted field.

Professor Bateson has said in his recently published 'Problems of Genetics': "When . . . we contemplate the problem of Evolution at large the hope at the present time of constructing even a mental picture of that process grows weak almost to the point of vanishing. We are left wondering that so lately men in general, whether scientific or lay, were so easily satisfied. Our satisfaction, as we now see, was chiefly founded on ignorance.'[1]

In view of this striking pronouncement on the part of one who has devoted his life with signal success to the experimental investigation of evolutionary problems, the remarks which I propose to lay before you for your consideration to-day may well appear rash and ill-advised. I cannot believe, however, that the position is really quite so black as it is painted. We must perforce admit that the divers theories with regard to the working of organic evolution cannot all be correct in all their details, but it may be that each contains its own elements of truth, and that if these elements can but be recognised and sorted out, they may perhaps be recombined in such a form as to afford at any rate a plausible working hypothesis. We must bear in mind from the outset that in dealing with such a complex problem many factors have to be taken into account, and that widely different views on the question may be merely one-sided and not necessarily mutually exclusive.

I take it there are three principal facts, or groups of facts, that have to be accounted for by any theory of organic evolution:—

(1) The fact that, on the whole, evolution has taken place in a progressive manner along definite and divergent lines.

(2) The fact that individual animals and plants are more or less precisely adapted in their organisation and in their behaviour to the conditions under which they have to live.

(3) The fact that evolution has resulted in the existence on the earth to-day of a vast number of more or less well-defined groups of animals and plants which we call species.

The first of these facts appears to me to be the most fundamental, and at the same time the one to which least attention is usually paid. The great question, after all, is, Why do organisms progress at all instead of remaining stationary from generation to generation? To answer this question it is not necessary to go back to the beginning and consider the case of the first terrestrial organisms, whatever they may have been, nor are we obliged to take as illustrations the lowest organisms known to us as existing at the present day. We may consider the problem at any stage of evolution, for at each stage progress is, or may be, still taking place. We may even begin by considering what is usually regarded as the highest stage of all, man himself; and indeed this seems the most natural thing to do, for we certainly know more about the conditions of progress in man than in any other organism. I refer, of course, at the moment, not to progress in bodily organisation, but to progress in the ordinary sense of the word, the progress, say, of a family which rises in the course of a few generations from a position of obscure poverty to one of wealth and influence. You may perhaps say that such a case has no bearing upon the problem of organic evolution in a state of nature, and that we ought to confine our attention to the evolution of bodily structure and function. If so, I must reply that you have no right to limit the meaning of the term evolution in this manner; the contrast between man and nature is purely arbitrary; man is himself a living organism, and all the improvements that he effects in his own condition are part of the progress of evolution in his particular case. At any rate I must ask you to accept this case as our first illustration of a principle that may be applied to organisms in general.

If we inquire into the cause of the progress of our human family I think there can be only one answer—it is due to the accumulation of capital, or, as I should prefer to put it, to the accumulation of potential energy, either in the form of material wealth or of education. What one generation saves is available for the next, and thus each succeeding generation gets a better start in life, and is able to rise a little higher than the preceding one.

Every biologist knows, of course, that there are many analogous cases amongst

the lower animals, and also amongst plants. The accumulation of food-yolk in the egg has undoubtedly been one of the chief factors in the progressive evolution of animals, although it has been replaced in the highest forms by a more effective method of supplying potential energy to the developing offspring. It may indeed be laid down as a general law that each generation, whether of animals or of plants, accumulates more energy than it requires for its own maintenance, and uses the surplus to give the next generation a start in life. There is every reason to believe that this has been a progressive process throughout the whole course of evolution, for the higher the degree of organisation the more perfect do we find the arrangements for securing the welfare of the offspring.

We cannot, of course, trace this process back to its commencement, because we know nothing of the nature of the earliest living things, but we may pause for a moment to inquire whether any phenomena occur amongst simple unicellular organisms that throw any light upon the subject. What we want to know is—How did the habit of accumulating surplus energy and handing it on to the next generation first arise?

Students of Professor H. S. Jennings' admirable work on the 'Behaviour of the Lower Organisms' will remember that his experiments have led him to the conclusion that certain Protozoa, such as Stentor, are able to learn by experience how to make prompt and effective responses to certain stimuli; that after they have been stimulated in the same way a number of times they make the appropriate response at once without having to go through the whole process of trial and error by which it was first attained. In other words, they are able by practice to perform a given action with less expenditure of energy. Some modification of the protoplasm must take place which renders the performance of an act the easier the oftener it has been repeated. The same is of course true in the case of the higher animals, and we express the fact most simply by saying that the animal establishes habits. From the mechanistic point of view we might say that the use of the machine renders it more perfect and better adapted for its purpose. In the present state of our knowledge I think we cannot go beyond this, but must content ourselves with recognising the power of profiting by experience as a fundamental property of living protoplasm.

It appears to me that this power of profiting by experience lies at the root of our problem, and that in it we find a chief cause of progressive evolution. Jennings speaks of the principle involved here as the 'Law of the readier resolution of physiological states after repetition,' and, similarly, I think we must recognise a 'Law of the accumulation of surplus energy' as resulting therefrom. Let us look at the case of the accumulation of food-yolk by the egg-cell a little more closely from this point of view. Every cell takes in a certain amount of potential energy in the form of food for it's own use. If it leads an active life, either as an independent organism or as a constituent part of an organism, it may expend by far the greater part, possibly even the whole, of that energy upon its own requirements, but usually something is left over to be handed down to its immediate descendants. If, on the other hand, the cell exhibits very little activity and expends very little energy, while placed in an environment in which food is abundant, it will tend to accumulate surplus energy in excess of its own needs. Such is the case with the egg-cells of the multicellular animals and plants. Moreover, the oftener the process of absorbing food-material is repeated the easier does it become; in fact, the egg-cell establishes a habit of storing up reserve material or food-yolk. Inasmuch as it is a blastogenic character, there can be no objection to supposing that this habit will be inherited by future generations of egg-cells. Indeed we are obliged to assume that this will be the case, for we know that the protoplasm of each succeeding generation of egg-cells is directly continuous with that of the preceding generation. We thus get at any rate a possibility of the progressive accumulation of potential energy in the germ-cells of successive generations of multicellular organisms, and of course the same argument holds good with regard to successive generations of Protista.

It would seem that progressive evolution must follow as a necessary result of the law of the accumulation of surplus energy in all cases where there is nothing to counteract that law, for each generation gets a better start than its predecessor, and is able to carry on a little further its struggle for existence with the environment. It may be said that this argument proves too much, that if it

were correct all organisms would by this time have attained to a high degree of organisation, and that at any rate we should not expect to find such simple organisms as bacteria and amœbæ still surviving. This objection, which, of course, applies equally to other theories of organic evolution, falls to the ground when we consider that there must be many factors of which we know nothing which may prevent the establishment of progressive habits and render impossible the accumulation of surplus energy. Many of the lower organisms, like many human beings, appear to have an inherent incapacity for progress, though it may be quite impossible for us to say to what that incapacity is due.

It will be observed that in the foregoing remarks I have concentrated attention upon the storing up of reserve material by the egg-cells, and in so doing have avoided the troublesome question of the inheritance of so-called acquired characters. I do not wish it to be supposed, however, that I regard this as the only direction in which the law of the accumulation of surplus energy can manifest itself, for I believe that the accumulation of surplus energy by the body may be quite as important as a factor in progressive evolution as the corresponding process in the germ-cells themselves. The parents, in the case of the higher animals, may supply surplus energy, in the form of nutriment or otherwise, to the offspring at all stages of its development, and the more capital the young animal receives the better will be its chances in life, and the better those of its own offspring.

In all these processes, no doubt, natural selection plays an important part, but, in dealing with the accumulation of food material by the egg-cells, one of my objects has been to show that progressive evolution would take place even if there were no such thing as natural selection, that the slow successive variations in this case are not chance variations, but due to a fundamental property of living protoplasm and necessarily cumulative.

Moreover, the accumulation of surplus energy in the form of food-yolk is only one of many habits which the protoplasm of the germ-cells may acquire in a cumulative manner. It may learn by practice to respond with increased promptitude and precision to other stimuli besides that of the presence of nutrient material in its environment. It may learn to secrete a protective membrane, to respond in a particular manner to the presence of a germ-cell of the opposite sex, and to divide in a particular manner after fertilisation has taken place.

Having thus endeavoured to account for the fact that progressive evolution actually occurs by attributing it primarily to the power possessed by living protoplasm of learning by experience and thus establishing habits by which it is able to respond more quickly to environmental stimuli, we have next to inquire what it is that determines the definite lines along which progress manifests itself.

Let us select one of these lines and investigate it as fully as the time at our disposal will permit, with a view to seeing whether it is possible to formulate a reasonable hypothesis as to how evolution may have taken place. Let us take the line which we believe has led up to the evolution of air-breathing vertebrates. The only direct evidence at our disposal in such a case is, of course, the evidence of palæontology, but I am going to ask you to allow me to set this evidence, which, as you know, is of an extremely fragmentary character, aside, and base my remarks upon the ontogenetic evidence, which, although indirect, will, I think, be found sufficient for our purpose. One reason for concentrating our attention upon this aspect of the problem is that I wish to show that the recapitulation of phylogenetic history in individual development is a logical necessity if evolution has really taken place.

We may legitimately take the nucleated Protozoon cell as our starting-point, for, whatever may have been the course of evolution that led up to the cell, there can be no question that all the higher organisms actually start life in this condition.

We suppose, then, that our ancestral Protozoon acquired the habit of taking in food material in excess of its own requirements, and of dividing into two parts whenever it reached a certain maximum size. Here again we must, for the sake of simplicity, ignore the facts that even a Protozoon is by no means a simple organism, and that its division, usually at any rate, is a very complicated

process. Each of the daughter-cells presently separates from its sister-cell and goes its own way as a complete individual, still a Protozoon. It seems not improbable that the separation may be due to the renewed stimulus of hunger, impelling each cell to wander actively in search of food. In some cases, however, the daughter-cells remain together and form a colony, and probably this habit has been rendered possible by a sufficient accumulation of surplus energy in the form of food-yolk on the part of the parent rendering it unnecessary for the daughter-cells to separate in search of food at such an early date. One of the forms of colony met with amongst existing Protozoa is the hollow sphere, as we see it, for example, in Sphærozoum and Volvox, and it is highly probable that the assumption of this form is due largely, if not entirely, to what are commonly called mechanical causes, though we are not in a position to say exactly what these causes may be. The widespread occurrence of the blastosphere or blastula stage in ontogeny is a sufficiently clear indication that the hollow, spherical Protozoon colony formed a stage in the evolution of the higher animals.

By the time our ancestral organism has reached this stage, and possibly even before, a new complication has arisen. The cells of which the colony is composed no longer remain all alike, but become differentiated, primarily into two groups, which we distinguish as somatic cells and germ-cells respectively.

From this point onwards evolution ceases to be a really continuous process, but is broken up into a series of ontogenies, at the close of each of which the organism has to go back and make a fresh start in the unicellular condition, for the somatic cells sooner or later become exhausted in their conflict with the environment and perish, leaving the germ-cells behind to take up the running. That the germ-cells do not share the fate of the somatic cells must be attributed to the fact that they take no part in the struggle for existence to which the body is exposed. They simply multiply and absorb nutriment under the protection of the body, and therefore retain their potential energy unimpaired. They are in actual fact, as is so often said, equivalent to so many Protozoa, and, like the Protozoa, are endowed with a potential immortality.

We know that, if placed under suitable conditions, or, in other words, if exposed to the proper environmental stimuli, these germ-cells will give rise to new organisms, like that in the body of which they were formerly enclosed. One of the necessary conditions is, with rare exceptions, the union of the germ-cells in pairs to form zygotes or fertilised ova; but I propose, in the first instance, for the sake of simplicity, to leave out of account the existence of the sexual process and the results that follow therefrom, postponing the consideration of these to a later stage of our inquiry. I wish, moreover, to make it quite clear that organic evolution must have taken place if no such event as amphimixis had ever occurred.

What, then, may the germ-cells be expected to do? How are they going to begin their development? In endeavouring to answer this question we must remember that the behaviour of an organism at any moment depends upon two sets of factors—the nature of its own constitution on the one hand, and the nature of its environment on the other. If these factors are identical for any two individual organisms, then the behaviour of these two individuals must be the same. If the germ-cells of any generation are identical with those of the preceding generation, and if they develop under identical conditions, then the soma of the one generation must also be identical with that of the other.[3] Inasmuch as they are parts of the same continuous germ-plasm—leaving out of account the complications introduced by amphimixis—we may assume that the germ-cells of the two generations are indeed identical in nearly every respect; but there will be a slight difference, due to the fact that those of the later generation will have inherited a rather larger supply of initial energy and a slightly greater facility for responding to stimuli of various kinds, for the gradual accumulation of these properties will have gone a stage further. The environment also will be very nearly identical in the two cases, for we know from experiment that if it were not the organism could not develop at all.

[3] This is, of course, a familiar idea. Compare Driesch, *Gifford Lectures*, 1907, p. 214.

Throughout the whole course of its ontogeny the organism must repeat with approximate accuracy the stages passed through by its ancestors, because at every stage there will be an almost identical organism exposed to almost identical stimuli. We may, however, expect an acceleration of development and a slight additional progress at the end of ontogeny as the result of the operation of the law of the accumulation of surplus energy and of the slightly increased facility in responding to stimuli. The additional progress, of course, will probably be so slight that from one generation to the next we should be quite unable to detect it, and doubtless there will be frequent backslidings due to various causes.

We can thus formulate a perfectly reasonable explanation of how it is that the egg first undergoes segmentation and then gives rise to a blastula resembling a hollow protozoon colony; it does so simply because at every stage it must do what its ancestors did under like conditions. We can also see that progressive evolution must follow from the gradual accumulation of additions at the end of each ontogeny, these additions being rendered possible by the better start which each individual gets at the commencement of its career.

Let us now glance for a moment at the next stage in phylogeny, the conversion of the hollow spherical protozoon colony into the cœlenterate type of organisation, represented in ontogeny by the process of gastrulation. Here again it is probable that this process is explicable to a large extent upon mechanical principles. According to Rhumbler,[3] the migration of endoderm cells into the interior of the blastula is partly due to chemotaxis and partly to changes of surface tension, which decreases on the inner side of the vegetative cells owing to chemical changes set up in the blastocœl fluid.

We may, at this point, profitably ask the question, Is the endoderm thus formed an inherited feature of the organism? The material of which it is composed is of course derived from the egg-cell continuously by repeated cell-division, but the way in which that material is used by the organism depends upon the environment, and we know from experiment that modifications of the environment actually do produce corresponding modifications in the arrangement of the material. We know, for example, that the addition of salts of lithium to the water in which certain embryos are developing causes the endoderm to be protruded instead of invaginated, so that we get a kind of inside-out gastrula, the well-known lithium larva.

It appears, then, that an organism really inherits from its parents two things: (1) a certain amount of protoplasm loaded with potential energy, with which to begin operations, and (2) an appropriate environment. Obviously the one is useless without the other. An egg cannot develop unless it is provided with the proper environment at every stage. Therefore, when we say that an organism inherits a particular character from its parents, all we mean is that it inherits the power to produce that character under the influence of certain environmental stimuli.[4] The inheritance of the environment is of at least as much importance as the inheritance of the material of which the organism is composed. The latter indeed is only inherited to a very small extent, for the amount of material in the egg-cell may be almost infinitesimal in comparison with the amount present in the adult, nearly the whole of which is captured from the environment and assimilated during ontogeny.

From this point of view the distinction between somatogenic and blastogenic characters really disappears, for all the characters of the adult organism are acquired afresh in each generation as a result of response to environmental stimuli during development. This is clearly indicated by the fact that you cannot change the stimuli without changing the result.

Time forbids us to discuss the phylogenetic stages through which the cœlenterate passed into the cœlomate type, the cœlomate into the chordate, and the chordate into the primitive vertebrate. We must admit that as yet we know nothing of the particular causes that determined the actual course of evolution at each successive stage. What we do know, however, about the influence of the environment, both upon the developing embryo and upon the adult, is suffi-

[3] Quoted by Przibram, *Experimental Zoology*, English Trans., Part I., p. 47.

[4] Compare Dr. Archdall Reid's suggestive essay on 'Biological Terms' (*Bedrock*, January 1914).

cient to justify us in believing that every successive modification must have been due to a response on the part of the organism to some environmental change. Even if the external conditions remained practically identical throughout long periods of time, we must remember that the internal conditions would be different in each generation, because each generation starts with a slightly increased capital and carries on its development a little further under internal conditions modified accordingly.

At this point it may be asked, Is the response to environmental stimuli a purely mechanical one, and, if so, how can we account for the fact that at every stage in its evolution the organism is adapted to its environment? We shall have to return to this question later on, but it may be useful to point out once more that there is good reason to believe—especially from the experimental work of Jennings—that the response of even a unicellular organism to stimuli is to a large extent purposive; that the organism learns by experience, by a kind of process of trial and error, how to make the response most favourable to itself under any given change of conditions; in other words, that the organism selects those modes of response that are most conducive to its own well-being. Under the term response to stimuli we must of course include those responses of the living protoplasm which result in modifications of bodily structure, and hence the evolution of bodily structure will, on the whole, be of an adaptive character and will follow definite lines. There is good reason for believing, however, that many minor modifications in structure may arise and persist, incidentally as it were, that have no significance as adaptations.

One of the most remarkable and distinctive features of the lower vertebrates is the presence of gill-slits as accessory organs of respiration. These gill-slits are clearly an adaptation to aquatic life. When the ancestors of the higher vertebrates left the water and took to life on land the gills disappeared and were replaced by lungs, adapted for air-breathing. The change must, of course, have been an extremely gradual one, and we get a very clear indication of how it took place in the surviving dipnoids, which have remained in this respect in an intermediate condition between the fishes and the amphibia, possessing and using both gills and lungs.

We also know that even the most highly specialised air-breathing vertebrates, which never live in water and never require gills or gill-slits at all, nevertheless possess very distinct gill-slits during a certain period of their development. This is one of the most familiar illustrations of the law of recapitulation, and my only excuse for bringing it forward now is that I wish, before going further, to consider a difficulty—perhaps more apparent than real—that arises in connection with such cases.

It might be argued that if gill-slits arose in response to the stimuli of aquatic life, and if these stimuli are no longer operative in the case of air-breathing vertebrates, then gill-slits ought not to be developed at any stage of their existence. This argument is, I think, fully met by the following considerations.

At any given moment of ontogenetic development the condition of any organ is merely the last term of a series of morphogenetic stages, while its environment at the same moment—which of course includes its relation to all the other organs of the body—is likewise merely the last term of a series of environmental stages. We have thus two parallel series of events to take into consideration in endeavouring to account for the condition of any part of an organism—or of the organism as a whole—at any period of its existence :—

$E_1\ E_2\ E_3$ . . . . E_n environmental stages.
$M_1\ M_2\ M_3$ . . . . M_n morphogenetic stages.

Ontogeny is absolutely conditioned by the proper correlation of the stages of these two series at every point, and hence it is that any sudden change of environment is usually attended by disastrous consequences. Thus, after the fish-like ancestors of air-breathing vertebrates had left the water and become amphibians, they doubtless still had to go back to the water to lay their eggs, in order that the eggs might have the proper conditions for their development.

Obviously the environment can only be altered with extreme slowness, and one of the first duties of the parent is to provide for the developing offspring conditions as nearly as possible identical with those under which its own develop-

ment took place. It is, however, inevitable that, as phylogenetic evolution progresses, the conditions under which the young organism develops should change. In the first place, the mere tendency to acceleration of development, to which we have already referred, must tend to dislocate the correlation between the ontogenetic series and the environmental series. Something of this kind seems to have taken place in the life-cycle of many Hydrozoa, resulting in the suppression of the free medusoid generation and the gradual degeneration of the gonophore. But it is probably in most cases change in the environment of the adult that is responsible for such dislocation.

To return to the case of the amphibians. At the present day some amphibians, such as the newts and frogs, still lay their eggs in water, while the closely related salamanders retain them in the oviducts until they have developed into highly organised aquatic larvæ, or even into what is practically the adult condition. Kammerer has shown that the period at which the young are born can be varied by changing the environment of the parent. In the absence of water the normally aquatic larvæ of the spotted salamander may be retained in the oviduct until they have lost their gills, and they are then born in the fully-developed condition, while, conversely, the alpine salamander, whose young are normally born in the fully-developed state, without gills, may be made to deposit them prematurely in water in the larval, gill-bearing condition.

There can be no doubt that the ancestral amphibians laid their eggs in water in a completely undeveloped condition. The habit of retaining them in the body during their development must have arisen very gradually in the phylogenetic history of the salamanders, the period for which the young were retained growing gradually longer and longer. It is obvious that this change of habit involves a corresponding change in the environmental conditions under which the young develop, and in cases in which the young are not born until they have reached practically the adult condition this change directly affects practically the whole ontogeny. We may say that the series

$$E_1\ E_2\ E_3\ \ldots\ldots\ldots\ E_n \text{ has become}$$
$$E_1'\ E_2'\ E_3'\ \ldots\ldots\ldots\ E_n',$$

and as the change of environment must produce its effect upon the developing organism the series

$$M_1\ M_2\ M_3\ \ldots\ldots\ldots\ M_n \text{ will have become}$$
$$M_1'\ M_2'\ M_3'\ \ldots\ldots\ldots\ M_n'.$$

We must remember that throughout the whole course of phylogenetic evolution this series is constantly lengthening, so that what was the adult condition at one time becomes an embryonic stage in future generations, and that the series thus represents not only the ontogeny, but also, though in a more or less imperfect manner, the phylogeny of the organism.

The character of each stage in ontogeny must depend upon (1) the morphological and physiological constitution of the preceding stage, and (2) the nature of the environment in which development is taking place. We cannot, however, distinguish sharply between those two sets of factors, for, in a certain sense, the environment gradually becomes incorporated in the organism itself as development proceeds, each part contributing to the environment of all the remainder, and the influence of this internal portion of the environment ever becoming more and more important.

The whole process of evolution depends upon changes of environment taking place so gradually that the necessary self-adjustment of the organism at every stage is possible. In the case of our amphibia the eggs could probably undergo the first stages of development, the preliminary segmentation, within the oviduct of the parent just as well as in the water, for in both cases they would be enclosed in their envelopes, and the morphological differences between the early stages in the two cases might be expected to be quite insignificant. But it must be the same at each term of the series, for each term is built upon the foundation of the preceding one, and the whole process takes place by slow and imperceptible degrees.

It is true that by the time we reach the formation of the vestigial gill-slits in the embryo of one of the higher vertebrates the environmental conditions are

very different from those under which gill-slits were developed in their aquatic ancestors. But what then? Are not the gill-slits also very different? The changed environment has had its effect. The gills themselves are never developed, and the gill-slits never become functional; moreover, they disappear completely at later stages of development, when the conditions of life become still more different and their presence would be actually detrimental to their possessor. The embryo with the vestigial gill-slits is, as a whole, perfectly well adapted to its environment, though the gill-slits themselves have ceased to be adaptive characters. They still appear because the environmental conditions, and especially the internal conditions, which have now become far more important than the external ones, are still such as to cause them to do so.

I think the chief difficulty in forming a mental picture of the manner in which evolution has taken place, and especially in accounting for the phenomenon of recapitulation in ontogeny, which is merely another aspect of the same problem, arises from attempting to take in too much at once. There is no difficulty in understanding how any particular stage is related to the corresponding stage in the previous generation, and the whole series of stages, whether looked at from the ontogenetic or from the phylogenetic point of view, can be nothing else but the sum of its successive terms.

It will be convenient, before going further, to sum up the results at which we have so far arrived from the point of view of the theory of heredity. We have as yet seen no reason to distinguish between somatogenic and blastogenic characters. All the characters of the adult animal are acquired during ontogeny as the result of the reaction of the organism to environmental stimuli, both internal and external. All that the organism actually inherits is a certain amount of protoplasm—endowed with a certain amount of energy—and a certain sequence of environmental conditions. In so far as these are identical in any two successive generations the final result must be identical also, the child must resemble the parent; in so far as they are different the child will differ from the parent, but the differences in environment cannot be very great without preventing development altogether.

So far, it is clear, there has been no need to think of the germ cells as the bearers of material factors or determinants that are responsible for the appearance of particular characters in the adult organism; nor yet to suppose that they are, to use the phraseology of the mnemic theory of heredity, charged with the memories of past generations. They have been regarded as simple protoplasmic units, and the entire ontogeny has appeared as the necessary result of the reaction between the organism and its environment at each successive stage of development. This cannot, however, be a complete explanation of ontogeny, for if it were we should expect all eggs, when allowed to develop under the same conditions from start to finish, to give rise to the same adult form, and this we know is not the case. We know also, from observation and experiment, that the egg is in reality by no means a simple thing but an extremely complex one, and that different parts of the egg may be definitely correlated with corresponding parts of the adult body. It has been demonstrated in certain cases that the egg contains special organ-forming substances definitely located in the cytoplasm, and that if these are removed definite parts of the organism into which the egg develops will be missing. We know, also, that the nucleus of the germ-cell of either sex contains—at any rate at certain periods—a number of perfectly well-defined bodies, the chromosomes, and these also have been definitely correlated in certain cases with special features of the adult organisation.

Before we can hope to complete our mental picture of the manner in which organic evolution has taken place, if only in outline, it is evident that we must be able to account for the great complexity of structure which the germ-cells themselves have managed to acquire, and also to form some idea of the effect of this complication upon the development of both the individual and the race.

We must consider the origin of cytoplasmic and nuclear complications of the egg separately, for they appear to be due fundamentally to two totally distinct sets of factors. In the first place we have to remember that during oogenesis the egg-cell grows to a relatively large size by absorbing nutrient material from the body in which it is enclosed. It is this nutrient material that is used for

the character of this nutrient material will change, during the course of evolution, *pari passu* with the changing character of the organism by which it is supplied. Doubtless the change is of a chemical nature, for we know from precipitin experiments that the body fluids of closely allied species, or even of the two sexes of the same species, do exhibit distinctly recognisable differences in chemical composition. It also appears highly probable, if not certain, from such experiments as those of Agar upon Simocephalus, that substances taken in with the food and which bring about conspicuous modifications of bodily structure, may at the same time be absorbed and stored up by the egg-cells so as to bring about corresponding changes in the adults into which the eggs develop.

There seems therefore to be no great difficulty in comprehending, at any rate in a general way, how the egg may become the repository of definite chemical substances, organ-forming substances if we like to call them so, possibly to be classed with the hormones and enzymes, which will influence the development in a particular manner as soon as the appropriate conditions arise.

Unfortunately, time will not allow of our following up this line of thought the present occasion, but we may notice, before passing on, that with the accumulation of organ-forming substances in the egg we have introduced the possibility of changes in bodily structure, to whatever cause they may be due, being represented by correlated modifications in the germ-cells, and this is doubtless one of the reasons why the germ-cells of different animals are not all alike with regard to their potentialities of development.[4]

We now come to the question of how the nucleus of the germ-cell acquired its great complexity of structure. We are not concerned here with the origin of the differentiation into nucleus and cytoplasm and the respective parts played by the two in the life of the cell. The problem which we have to consider is the complication introduced by the sexual process, by the periodically recurring union of the germ-cells in pairs, or, as Weismann has termed it, amphimixis. This is well known to be essentially a nuclear phenomenon, in which the so-called chromatin substance is especially concerned, and it is a phenomenon which must have made its appearance at a very early stage of evolution, for it is exhibited in essentially the same manner alike in the higher plants and animals and in unicellular organisms.

Let us suppose, for the sake of argument, that when amphimixis first took place the chromatin of each germ-cell was homogeneous, but that it differed slightly in different germ-cells of the same species as a result of exposure to slightly different conditions during its past history. What would be likely to happen when two different samples of chromatin came together in the zygote? The result would surely depend upon the interaction of the complex colloidal multimolecules of which the chromatin is composed. Various possibilities would arise. (1) The two samples might differ in such a way as to act as poisons to one another, disturbing each other's molecular equilibrium to such an extent that neither could survive. This is possibly what happens when an ovum is fertilised by a spermatozoon of a distinct species, though there are, of course, exceptions. (2) They might be so alike as to be able to amalgamate more or less completely so that there would simply be an increase of chromatin of possibly more or less modified constitution. (3) They might continue to exist side by side, each maintaining its own individual character.

In the third case the union of the two different samples would give rise to a mass of chromatin of twofold nature, and repetition of the process from generation to generation would, as Weismann has shown, result in ever-increasing heterogeneity, until the chromatin came to consist of a great number of different concrete particles, each of which might conceivably differ from all the others. But when two heterogeneous masses of chromatin meet in the zygote there may be all sorts of mutual attractions and repulsions between the different colloidal multimolecules, for all three of our supposed cases may arise simultaneously and thus the results may become extremely complicated.

The chromatin of the germ-cells in all existing organisms is undoubtedly heterogeneous, and this heterogeneity may be to some extent visibly expressed

[4] Cf. Cunningham's 'Hormone Theory' of Heredity (*Archiv für Entwicklungsmechanik der Organismen*, Bd. xxvi. Heft 3).

may provisionally accept Weismann's view that these chromosomes are themselves heterogeneous, being composed of chromomeres or ids, which in their turn are composed of determinants.

All this complexity of structure may be attributed to the effects of oft-repeated amphimixis, a view which is supported in the most striking manner by the fact that the nucleus in all ordinary somatic cells (in animals and in the diploid generation of plants) has a double set of chromosomes, one derived from the male and the other from the female parent, and by the well-known phenomenon of chromatin reduction which always precedes amphimixis.

When we approach the problem of heredity from the experimental side we get very strong evidence of the existence in the germ-plasm of definite material substances associated with the inheritance of special characters. Mendelian workers generally speak of these substances as factors, but the conception of factors is evidently closely akin to that of Weismann's hypothetical determinants. The cytological evidence fits in very well with the view that the factors in question may be definite material particles, and it is quite possible that such particles may have a specific chemical constitution to which their effects upon the developing organism are due.

From our point of view the interesting thing is the possibility that arises through the sexual process of the permutation and combination of different factors derived from different lines of descent. A germ-cell may receive additions to its collection of factors or be subject to subtractions therefrom, and in either case the resulting organism may be more or less conspicuously modified.

By applying the method of experimental hybridisation a most fruitful and apparently inexhaustible field of research has been opened up in this direction, in the development of which no one has taken a more active part than the present President of the British Association. There cannot be the slightest doubt that a vast number of characters are inherited in what is called the Mendelian manner, and, as they are capable of being separately inherited and interchanged with others by hybridisation, we are justified in believing that they are separately represented in the germ-cells by special factors. Important as this result is I believe that at the present time there exists a distinct danger of exaggerating its significance. The fact that many new and apparently permanent combinations of characters may arise through hybridisation, and that the organisms thus produced have all the attributes of what we call distinct species, does not justify us in accepting the grotesque view—as it appears to me—that all species have arisen by crossing, or even the view that the organism is entirely built up of separately transmissible 'unit characters.'

Bateson tells us that 'Baur has for example crossed species so unlike as *Antirrhinum majus* and *molle*, forms differing from each other in almost every feature of organisation.' Surely the latter part of this statement cannot be correct, for after all *Antirrhinum majus* and *molle* are both snapdragons, and exhibit all the essential characters of snapdragons.

I think it is a most significant fact that the only characters which appear to be inherited in Mendelian fashion are comparatively trivial features of the organism which must have arisen during the last stages of phylogeny. This is necessarily the case, for any two organisms sufficiently nearly related to be capable of crossing are identical as regards the vast majority of their characters. It is only those few points in which they differ that remain to be experimented on. Moreover, the characters in question appear to be all non-adaptive, having no obvious relation to the environment and no particular value in the struggle for existence. They are clearly what Weismann calls blastogenic characters, originating in the germ-plasm, and are probably identical with the mutations of de Vries. These latter are apparently chromatin-determined characters, for, as Dr. Gates has recently shown in the case of *Œnothera*, mutation may result from abnormal distribution of the chromosomes in the reduction division.*

We have next to inquire whether or not the Mendelian results are really in any way inconsistent with the general theory of evolution outlined in the earlier part of this address. Here we are obviously face to face with the old dispute between epigenesis and preformation. The theory of ontogeny which I first

* *Quarterly Journal of Microscopical Science*, vol. 59, p. 557.

put forward is clearly epigenetic in character, while the theory of unit characters, represented in the germ-cells by separate 'factors,' is hardly less clearly a theory of preformation, and of course the conception of definite organ-forming substances in the cytoplasm falls under the same category. The point which I now wish to emphasise is that the ideas of epigenesis and preformation are not inconsistent with one another, and that, as a matter of fact, ontogenetic development is of a dual nature, an epigenesis modified by what is essentially preformation.

We have already dealt briefly with the question of organ-forming substances in the cytoplasm, and it must, I think, be clear that the existence of these is in no way incompatible with a fundamental epigenesis. We shall find directly that the same is true of Mendelian 'factors' or Weismannian 'determinants.'

We have seen that it is possible to conceive of even a complex organism as inheriting nothing from its parent but a minute speck of protoplasm, endowed with potential energy, and a sequence of suitable environments, the interaction between the two bringing about a similar result in each succeeding generation, with a slow progressive evolution due to the operation of the law of accumulation of surplus energy. If any of the conditions of development are changed the result, as manifested in the organisation of the adult, must undergo a corresponding modification. Suppose that the chromatin substance of the zygote is partially modified in molecular constitution, perhaps by the direct action of the environment, as appears to happen in the case of Tower's experiments on mutation in the potato beetle, or by the introduction of a different sample of chromatin from another individual by hybridisation. What is the germ-plasm now going to do? When and how may the changes that have taken place in its constitution be expected to manifest themselves in the developing organism?

Let us consider what would be likely to happen in the first stages of ontogeny. If the germ-plasm had remained unaltered the zygote would have divided into blastomeres under the stimuli of the same conditions, both internal and external, as those under which the corresponding divisions took place in preceding generations. Is the presence of a number of new colloidal multimolecules in the germ-plasm going to prevent this? The answer to this question probably depends partly upon the proportion that the new multimolecules bear to the whole mass, and partly upon the nature of the modification that has taken place. If the existence of the new multimolecules is incompatible with the proper functional activity of the germ-plasm as a whole there is an end of the matter. The organism does not develop. If it is not incompatible we must suppose that the zygote begins its development as before, but that sooner or later the modification of the germ-plasm will manifest itself in the developing organism, in the first instance as a mutation. In cases of hybridisation we may get a mixture in varying degrees of the distinguishing characters of the two parent forms, or we may get complete dominance of one form over the other in the hybrid generation, or we may even get some new form, the result depending on the mutual reactions of the different constituents of the germ-plasm.

The organism into which any zygote develops must be a composite body deriving its blastogenic characters from different sources; but this cannot affect its fundamental structure, for the two parents must have been alike in all essential respects or they could not have interbred, and any important differences in the germ-plasm must be confined to the 'factors' for the differentiating characters. The fundamental structure still develops epigenetically on the basis of an essentially similar germ-plasm and under essentially similar conditions as in the case of each of the two parents, and there is no reason to suppose that special 'factors' have anything to do with it.

We thus see how new unit characters may be added by mutation and interchanged by hybridisation while the fundamental constitution of the organism remains the same and the epigenetic course of development is not seriously affected. All characters that arise in this way must be regarded, from the point of view of the organism, as chance characters due to chance modifications of the germ-plasm, and they appear to have comparatively little influence upon the course of evolution.

One of the most remarkable features of organic evolution is that it results in the adaptation of the organism to its environment, and for this adaptation

mutation and hybridisation utterly fail to account. Of course the argument of natural selection is called in to get over this difficulty. Those organisms which happen to exhibit favourable mutations will survive and hand on their advantages to the next generation, and so on. It has frequently been pointed out that this is not sufficient. Mutations occur in all directions, and the chances of a favourable one arising are extremely remote. Something more is wanted, and this something, it appears to me, is to be found in the direct response of the organism to environmental stimuli at all stages of development, whereby individual adaptation is secured, and this individual adaptation must arise again and again in each succeeding generation. Moreover, the adaptation must, as I pointed out before, tend to be progressive, for each successive generation builds upon a foundation of accumulated experience and has a better start than its predecessors.

Of course natural selection plays its part, as it must in all cases, even in the inorganic world, and I believe that in many cases—as for example in protective resemblance and mimicry—that part has been an extremely important one. But much more important than natural selection appears to me what Baldwin[7] has termed 'Functional Selection,' selection by the organism itself, out of a number of possible reactions, of just those that are required to meet any emergency. As Baldwin puts it, 'It is the organism which secures from all its overproduced movements those which are adaptive and beneficial.' Natural selection is here replaced by intelligent selection, for I think we must agree with Jennings[8] that we cannot make a distinction between the higher and the lower organisms in this respect, and that all purposive reactions, or adjustments, are essentially intelligent.

Surely that much-abused philosopher, Lamarck, was not far from the truth when he said, 'The production of a new organ in an animal body results from a new requirement which continues to make itself felt, and from a new movement which this requirement begets and maintains.'[9] Is not this merely another way of saying that the individual makes adaptive responses to environmental stimuli? Where so many people fall foul of Lamarck is with regard to his belief in the inheritance of acquired characters. But in speaking of acquired characters Lamarck did not refer to such modifications as mutilations; he was obviously talking of the gradual self-adjustment of the organism to its environment.

We are told, of course, that such adjustments will only be preserved so long as the environmental stimuli by which they were originally called for continue to exercise their influence. Those who raise this objection are apt to forget that this is exactly what happens in evolution, and that the *sine qua non* of development is the proper maintenance of the appropriate environment, both internal and external. Natural selection sees to it that the proper conditions are maintained within very narrow limits.

A great deal of the confusion that has arisen with regard to the question of the inheritance of acquired characters is undoubtedly due to the quite unjustifiable limitation of the idea of 'inheritance' to which we have accustomed ourselves. The inheritance of the environment is, as I have already said, just as important as the inheritance of the material foundation of the body, and whether or not a newly acquired character will be inherited must depend, usually at any rate, upon whether or not the conditions under which it arose are inherited. It is the fashion nowadays to attach very little importance to somatogenic characters in discussing the problem of evolution. The whole fundamental structure of the body must, however, according to the epigenetic view, be due to the gradual accumulation of characters that arise as the result of the reactions of the organism to its environment, and which are therefore somatogenic, at any rate in the first instance, though there is reason to believe that some of them may find expression in the germ-cells in the formation of organ-forming substances, and possibly in other ways. Blastogenic characters which actually originate in the germ-cells appear to be of quite secondary importance.

We still have to consider the question, How is it that organic evolution has

[7] *Development and Evolution* (New York, 1902), p. 87.
[8] *Behaviour of the Lower Organisms* (New York, 1906), pp. 334, 335.
[9] *Histoire naturelle des Animaux sans Vertèbres*, tom. i. 1815, p. 185.

led to the formation of those more or less well-marked groups of organisms which we call species? We have to note in the first place that there is no unanimity of opinion amongst biologists as to what a species is. Lamarck insisted that nature recognises no such things as species, and a great many people at the present day are, I think, still of the same opinion. In practice, however, every naturalist knows that there are natural groups to which the vast majority of individuals can be assigned without any serious difficulty. Charles Darwin maintained that such groups arose, under the influence of natural selection, through gradual divergent evolution and the extinction of intermediate forms. To-day we are told by de Vries that species originate as mutations which propagate themselves without alteration for a longer or shorter period, and by Lotsy that species originate by crossing of more or less distinct forms, though this latter theory leaves quite unsolved the problem of where the original forms that crossed with one another came from.

I think a little reflection will convince us that the origin of species is a different problem from that of the cause of progressive evolution. We can hardly doubt, however, that Darwin was right in attributing prime importance to divergent evolution and the disappearance of connecting links. It is obvious that this process must give rise to more or less sharply separated groups of individuals to which the term species may be applied, and that the differences between these species must be attributed ultimately to differences in the response of the organism to differing conditions of the environment. It may be urged that inasmuch as different species are often found living side by side under identical conditions the differences between them cannot have arisen in this way but we may be quite certain that if we knew enough of their past history we should find that their ancestors had not always lived under identical conditions.

The case of flightless birds on oceanic islands is particularly instructive in this connection. The only satisfactory way of explaining the existence of such birds is by supposing that their ancestors had well developed wings, by the aid of which they made their way to the islands from some continental area. The conditions of the new environment led to the gradual disuse and consequent degeneration of the wings until they either became useless for flight or, in the case of the moas, completely disappeared. It would be absurd to maintain that any of the existing flightless birds are specifically identical with the ancestral flying forms from which they are descended, and it would, it appears to me, be equally absurd to suppose that the flightless species arose by mutation or by crossing, the same result being produced over and over again on different islands and in different groups of birds. This is clearly a case where the environment has determined the direction of evolution.

In such cases there is not the slightest ground for believing that crossing has had anything whatever to do with the origin of the different groups to which the term species is applied; indeed the study of island faunas in general indicates very clearly that the *prevention* of crossing, by isolation, has been one of the chief factors in the divergence of lines of descent and the consequent multiplication of species, and Romanes clearly showed that even within the same geographical area an identical result may be produced by mutual sterility, which is the cause, rather than the result, of specific distinction.

Species, then, may clearly arise by divergent evolution under changing conditions of the environment, and may become separated from one another by the extinction of intermediate forms. The environmental stimuli (including, of course, the body as part of its own environment) may, however, act in two different ways: (1) Upon the body itself, at any stage of its development, tending to cause adaptation by individual selection of the most appropriate response; and (2) upon the germ-plasm, causing mutations or sudden changes, sports, in fact which appear to have no direct relation whatever to the well-being of the organism in which they appear, but to be purely accidental. Such mutations are, of course, inherited, and, inasmuch as the great majority of specific characters appear to have no adaptive significance, it seems likely that mutation has had a great deal to do with the origin of species, though it may have had very little to do with progressive evolution.

Similarly with regard to hybridisation, we know that vast numbers of distinct forms, that breed true, may be produced in this way, but they are simply due to recombinations of mutational characters in the process of amphimixis, an

have very little bearing upon the problem of evolution. If we like to call the new groups of individuals that originate thus 'species,' well and good, but it only means that we give that name, as a matter of convenience, to any group of closely related individuals which are distinguished by recognisable characters from the individuals of all other groups, and which hand on those characters to their descendants so long as the conditions remain the same. This, perhaps, is what we should do, and just as we have learnt to regard individuals as the temporary offspring of a continuous stream of germ-plasm, so we must regard species as the somewhat more permanent but nevertheless temporary offshoots of a continuous line of progressive evolution. Individuals are to species what the germ-plasm is to individuals. One species does not arise from another species, but from certain individuals in that species, and when all the individuals become so specialised as to lose their power of adaptation, then changes in the environment may result in the extinction of that line of descent.

It is hardly necessary to point out that no explanation that we are able to give regarding the causes of either phylogenetic or ontogenetic evolution can be complete and exhaustive. Science can never hope to get to the bottom of things in any department of knowledge; there is always something remaining beyond our reach. If we are asked why an organism chooses the most appropriate response to any particular stimulus, we may suggest that this is the response that relieves it from further stimulation, but we cannot say how it learns to choose that response at once in preference to all others. If we are asked to account for some particular mutation, we may say that it is due to some modification in the constitution or distribution of the chromosomes in the germ-cells, but even if we knew exactly what that modification was, and could express it in chemical terms, we could not really say why it produces its particular result and no other, any more than the chemist can say why the combination of two gases that he calls oxygen and hydrogen gives rise to a liquid that he calls water.

There is one group of ontogenetic phenomena in particular that seem to defy all attempts at mechanistic interpretation. I refer to the phenomena of restitution, the power which an organism possesses of restoring the normal condition of the body after it has been violently disturbed by some external agent. The fact that a newt is able to regenerate its limbs over and over again after they have been removed, or that an echinoderm blastula may be cut in half and each half give rise to a perfect larva, is one of the most surprising things in the domain of biological science. We cannot, at present at any rate, give any satisfactory mechanistic explanation of these facts, and to attribute them to the action of some hypothetical Entelechy, after the manner of Professor Hans Driesch, is simply an admission of our inability to do so. We can only say that in the course of its evolution each organism acquires an individuality or wholeness of its own, and that one of the fundamental properties of living organisms is to maintain that individuality. They are able to do this in a variety of ways, and can sometimes even replace a lost organ out of material quite different from that from which the organ in question is normally developed, as in the case of the regeneration of the lens of the eye from the iris in the newt. That there must be some mechanism involved in such cases is, of course, self-evident, and we know that that mechanism may sometimes go wrong and produce monstrous and unworkable results; but it is, I think, equally evident that the organism must possess some power of directing the course of events, so as generally to secure the appropriate result; and it is just this power of directing chemical and physical processes, and thus employing them in its own interests, that distinguishes a living organism from an inanimate object.

In conclusion I ought, perhaps, to apologise for the somewhat dogmatic tone of my remarks. I must ask you to believe, however, that this does not arise from any desire on my part to dogmatise, but merely from the necessity of compressing what I wished to say into a totally inadequate space. Many years of patient work are still needed before we can hope to solve, even approximately, the problem of organic evolution, but it seemed to me permissible, on the present occasion, to indulge in a general survey of the situation, and see how far it might be possible to reconcile conflicting views and bring together a number of ideas derived from many sources in one consistent theory.

The following Papers and Reports were then read :—

1. *Plankton.* *By* Professor HERDMAN, *F.R.S.*

2. *Exhibition of Lantern Slides of the Narwhal and Beluga.* *By* Professor H. JUNGERSEN.

3. *Some Notes on a Collection of Australian Frogs.* *By* J. BOOTH, *M.C.E.*, *B.Sc.*

The work of which this paper is the outcome was undertaken in the hope of finding some method of determination and identification of Batrachian species, without resort to the slight dissection necessary to examine the sternal apparatus and the sacral vertebræ. The material made use of was the collection of frogs at the Melbourne University, together with some of the specimens from the National Museum, and a few privately collected.

In accordance with this original intention, stress was laid on external shape, and in order to render the description of shape more definite the particulars were expressed as far as possible numerically and in proportional measurements. The length of the specimen, from snout to vent, was taken as a basis, and other dimensions expressed in terms of it.

To facilitate these measurements, a scale was devised, by which the length of the specimen in millimètres, and other dimensions in proportional units, could easily be read off from the callipers. The particulars selected as most satisfactory for measurement were :—The depth of the chest; the length and breadth of the head; the length of the snout; the distances from eye to nostril, and between the nares; the diameter of the orbit; the width of the upper eyelid; the distance between the orbits; the diameter of the tympanum, and distance from tympanum to eye; the length of hind limb; and the length of the digits of the hand. These dimensions have been tabulated for a large number of specimens.

It was found that the description and measurement of external features could not replace observations of the skeletal girdles, the variations in which seem to be of paramount genetic significance; while the external configuration and aspect is more related to the mode of life of the animals, and largely corresponds with the classification into:—swimming, climbing or tree, and burrowing or cryptic frogs.

In the course of the work the relative value of the external characters came under review. Of these, amount of webbing on the toes seems to have been overrated, Professor Spencer having pointed out how very variable this character is in several species collected by him in the interior. Colour and markings are very definite in some cases, remarkably variable in others; but usually varying in such a way as to suggest a normal form from which the rest may be derived. This normal is probably to be found in strongly marked young specimens. Of particular markings, the vertebral line, in some species constant, in others, though normal, varies in distinctness to total absence, and again in others is very definitely present or absent. Another normal marking is the lateral face-streak, and nearly all face colourations may be considered as variations of this. An external feature closely connected with habit is the adpression of the thigh to the groin. In some species this gives rise to a difference of colour and texture in the concealed parts, while in others the groin is fully exposed and does not differ from the general surface.

With regard to classification, the scheme of the British Museum Catalogue, as applied to Australian frogs, becomes reduced to three families of the Arcifera, *Cystignathidæ*, *Hylidæ*, and *Bufonidæ*, and (on account of the record of three species of the genus *Austrochaperina*, Fry) the family *Ranidæ* of the Firmisterna.

A list of the Australian species, with references to descriptions and notes on the specimens examined, and tables of the proportionally measured dimensions, were appended.

4. *Species of Victorian Lampreys.* *By* J. A. Leach, *D.Sc.*

Richardson (1848) was the first to name an Australian lamprey (*Petromyzon mordax*).

Gray, in the British Museum Catalogue (1851), made Richardson's specimen the type of his genus *Mordacia*, and made two other Australian lampreys the types of his genera *Geotria* and *Velasia*.

Günther, in 'The Catalogue of Fishes in the British Museum' (1870), accepted *Mordacia mordax*, but included *Velasia* in the genus *Geotria*. Günther later gave the name *Geotria allportii* to a Tasmanian specimen. Ogilby and Regan both include this species in *Geotria australis*.

Count Castlenau (1872) created two new genera founded on immature forms, thus increasing the Australian species to six. Ogilby (1894), in 'A Monograph of the Australian Marsipobranchii,' reduced the species and genera to three. He revived Gray's genus *Velasia* and named the Australian form *V. stenostoma*, though he did not specify characters to separate it from *V. chilensis*.

Plate included *Velasia* in *Geotria*, but separated *G. stenostoma* from *G. chilensis*; he considered that both occur in Australia.

Regan, in 'A Synopsis of the Marsipobranchs of the Order *Hyperoartii*' (1911), placed the Australian species in *G. stenostoma* and restricted the species *G. chilensis* to South America. He created a new species (*G. saccifera*) for a New Zealand specimen of the pouched form.

An examination of forty-six specimens of lampreys in the University Museum and National Museum, Melbourne, showed two species of *Mordacia*, and that a new species of *Geotria* is required for specimens intermediate between the broad-headed, pouched form and the narrow-headed *Velasia* form; as these connect the two extremes it is unnecessary to retain *Velasia* as a separate genus.

The great variation in the chief characters, and the small number of lampreys available for examination, are undoubtedly the chief causes of the creation of so many species, and the discarding of these by subsequent workers.

The horny teeth are easily removed and the appearance of the mouth after their removal is different. The state of distension of the mouth revealing the whole of the teeth or the points only of the tongue teeth and supraoral teeth is important in determining the appearance of these structures. Even the teeth of the supraoral laminæ, a generic characteristic, at least, vary. Plate figures a *Geotria* with five cusps instead of four on the supraoral lamina. One *Mordacia* examined has four pointed cusps on one lamina, while the lamina of the other side has three. Castlenau said: 'I find the greatest difficulty in the determination of the Victorian fishes of this family. . . . The most important character, the dentition, seems to be subject to the most extraordinary variations; in fact, I cannot find it exactly similar in two specimens.'

Regan used the relation of the length of the first dorsal fin to the distance between the two dorsal fins as one of three distinguishing characters. In six specimens of *Geotria chilensis* taken alive during an eel fare at the Hopkins River Falls near Warrnambool, the interspace varied from ·6 of the length of the fin to 1·3 times the length, a variation of over 100 per cent. Regan used this as one of three variable characters when separating nine specimens of *Geotria* into four species.

Ogilby regarded the presence of pores on *Velasia* as a generic character. Pores occur on all the specimens of *Geotria* and *Velasia* examined. On one large pouched *Geotria australis* the pores form a definite 'lateral line.' Plate figured pores on each species he recognised.

The pouch is a puzzle. It is not a secondary sexual character for it occurs in both sexes.

It seems necessary to recognise five species of Victorian lampreys.

5. *Notes on the Ringing of Birds.* *By* E. D. de Hamel.

Aluminium bands of different sizes stamped with the address 'Witherby, High Holborn, London,' and also bearing a distinctive number, are bent into an

open-sided ring which can readily be passed over the tarsus of a bird and closed, taking care that it can move easily between the foot and the knee, and the bird is then released.

The species number, date, locality, and circumstances are recorded on a form supplied with each packet of twenty rings. These rings are issued by Messrs. Witherby to subscribers to their magazine 'British Birds' who are willing to assist, and are carefully registered.

When one of these marked birds is recaptured and the incident reported the information is added to the register, and from these details an annual report with maps is prepared, and published by Messrs. Witherby under the auspices of the British Ornithologists' Club, the eighth, for 1913, being now ready. Thus the ultimate course and length of bird migration will be defined.

It is requested that all wild birds may be ringed, as it is found that even the most constant varieties wander to considerable distances.

A very large number of rings have been utilised, and about five per cent. of these retaken and reported. In addition to the English scheme, this work is being carried on by Professor Mortensen from Viborg in Denmark, and by others in Germany. The results are most encouraging. Adult swallows marked in pairs have been traced from Ayrshire and Staffordshire in England to Natal and the Orange Free State in Africa, and back to Staffordshire, but in each case only one of the pair has been retaken as they always have new mates.

Nestlings seldom return to their birth-place. Thrushes, blackbirds, and robins marked in England have been recaptured in Ireland and France. Cormorants, nestlings from Wexford in Ireland, in Finisterre, Brittany, Portugal, and Spain; mallard and wild duck in France; a pochard I marked in Warwickshire was retaken six months later at Butzow in Mecklenburg; a turtle-dove in Portugal.

Abroad the same work has been carried on since 1898, and a starling from Russia reached Yorkshire; a widgeon from Denmark reached Wales; tufted duck from Finland reached Ireland, and a Prussian black-headed gull was recaptured in Norfolk.

6. *Report on the Biological Problems incidental to the Belmullet Whaling Station.*—See Reports, p. 125.

7. *Report of the Committee on the Marine Laboratory, Plymouth.* See Reports, p. 163.

8. *Report on the Occupation of a Table at the Zoological Station at Naples.*—See Reports, p. 162.

9. *Report on the Position of the Antarctic Whaling Industry.* See Reports, p. 123.

10. *Final Report on Experiments in Inheritance.*—See Reports, p. 163.

11. *Report of the Committee on the Nomenclator Animalium Genera et Sub-genera.*

12. *Report on the Feeding Habits of British Birds.*

13 *Report on the Inheritance and Development of Secondary Sexual [illegible]rs in Birds.*

—. *Report on Zoology Organisation.*

15 *Report on the Formulation of a Definite System on which Collectors should record their Captures*

16 *Report on a Natural History Survey of the Isle of Man*

WEDNESDAY, AUGUST 19.

The following Papers were read :—

1. *On Scent-Distributing Apparatus in the Lepidoptera.* *By* F. A. Dixey, *M.D.*, *F.R.S.*

It is well known that certain specialised scales found in various situations on the wings, bodies, and limbs of Lepidoptera are concerned in the distribution of a scent, which in many cases is characteristic of the species. These scales may occur in both sexes, but certain forms of them have only been found in males; among these are the plume-scales of the Pierines and Nymphalines. The Pierine plume-scale often affords a ready means of identifying the species, and is frequently of service in throwing light on questions of affinity. Thus, the interesting butterfly *Leuciacria acuta* Roths. and Jord., recently discovered in New Guinea, has been considered by some authorities to be nearly akin to the African genus *Pinacopteryx*, and by others to the Australasian genus *Elodina*. But the scent-scales with which it is abundantly furnished bear no resemblance to those of any *Pinacopteryx*, while *Elodina* appears to be entirely devoid of these structures. On the other hand, the scent-scales of *Leuciacria* strongly recall those of *Delias*, a genus well represented in the Australian Province, and especially so in New Guinea. Scales of a somewhat similar character are also found in *Huphina*, another genus with an Oriental and Australasian distribution, and probably not far removed from *Delias* in point of affinity. In a further structural feature *Leuciacria* is nearer to *Huphina* than it is to *Delias*, and it may possibly turn out to be a connecting link between these two assemblages. But from the evidence of the scent-scales it seems safe to conclude that such resemblance as exists to *Pinacopteryx* and *Elodina* is only superficial. The well-known 'battledore scales' that occur on the wings of Lycænids furnish a means of separating two species, *Plebeius ægon* and *P. argyrognomon*, which are often indistinguishable by ordinary methods of examination.

In some cases, though not in all, a special adaptation exists with the object of economising the scent until it is required for purposes of sexual recognition or attraction. The costal folds of the forewing in many Hesperids, noticed by Doubleday and Westwood, and first adequately described by Fritz Müller, are examples of this kind of provision. Another structural feature serving the same purpose is the collection of the scent-distributing scales into a patch on that portion of the fore or hind wing which is covered in the position of rest. This arrangement is seen in many Pierines; it occurs also in Satyrines and Nymphalines. No example of a male characterised by special scent-scales was known to Fritz Müller among the Erycinids. Such, however, do exist; as, for example, in the genera *Mesosemia* and *Pandemos*, where the scent-patches occlude one another in the attitude of rest, as notably in the genus *Dismorphia*

Danainæ and their allies, the tropical American *Ithomiinæ*, always tend to be mimicked by other butterflies, although their patterns in each of the great tropical regions are for the most part very different from those in the others. The same conclusions emerge when other great groups of models are compared, and the whole body of facts affords strong indirect evidence in support of the hypothesis that mimicry is an advantageous resemblance which has grown up under the influence of natural selection.

Australia is the most isolated of all the inhabited continental tracts on the earth's surface, and its isolation is reflected in its peculiar fauna and flora. How far is it reflected in the insect-models and their mimics? Up to the present time the subject has been but little studied in Australian material, but we can nevertheless see our way to certain conclusions of much interest.

Perhaps the most widely spread models in the world are the black yellow-banded stinging Hymenoptera. The central members of these powerful combinations are wasps (Diploptera), around which are ranged sand-wasps (Fossores), and, in far smaller numbers, bees (Anthophila), followed by mimetic species of the Phytophagous Hymenoptera, and of other orders—Diptera, Coleoptera Lepidoptera, etc. Throughout this dominant combination of models and mimic the subcylindrical body is black, encircled by many bright yellow bands. Although widespread over the world it is especially powerful in the north temperate zone. In Australia, however, its place is taken by a combination with a very distinct pattern. The bands are deep brownish orange instead of bright yellow, and they are few and broad instead of many and narrow. This pattern runs through a large and complex set of models and mimics. It is very convincing to compare such a mimetic Asilid fly as the European *Asilus crabroniformis* with the Australian species, and to observe how their very different patterns resemble those of the respective Aculeate models. An equally significant comparison may be drawn between the mimetic Longicorn beetles of these two parts of the world.

The conspicuous sluggish Lycid beetles form another dominant group of models in all the tropical regions, and here, too, a powerful Australian combination exhibits a peculiar colouring, and in some respects a peculiar constitution.

Material already received from Commander J. J. Walker in the Sydney district and from Mr. A. Eland Shaw at Healesville, Victoria, shows that the Australian contribution to the study of mimicry is sure to be of the highest interest and importance.

Reports, p. 163.

TUESDAY, AUGUST 18.

Joint Discussion with Section K on the Nature and Origin of Species.
See p. 579.

The following Papers were then read :-

1. *An Expedition to the Abrolhos Islands. By* Professor W. J. Dakin.

Some Features in the Diurnal Migrations of Pipits, Wagtails, and Swallows, as observed at Tuskar Rock Light-Station, Co. Wexford. By Professor C. J. Patten, *M.A., M.D., Sc.D.*

In certain periods of spring and autumn a stream or procession of migrants passes the Tuskar Rock Light-station daily. Owing to the barren nature of the Rock—wave-swept to a large extent in rough weather—paucity of food, and lack of fresh water, comparatively few of the travellers descend and alight. As they hasten past, the altitude of their flight relative to the level of the lantern is a matter of interest, seeing that so many nocturnal migrants strike the glass.

Most birds direct their flight towards the land, *i.e.*, S.E. to N.W. or due E. to W. Even birds presumably on emigration seem to make for the land. Pipits and wagtails travel about twenty miles an hour; swallows and martins about 90 miles an hour. On account of the very limited area of the Rock and the considerable altitude at which many of the birds fly, the descending flight for the purpose of alighting, when attempted, is almost perpendicular. Several original photographs from life of the species dealt with in this paper have been secured and used as illustrations.

Sydney.

FRIDAY, AUGUST 21.

The following Papers were read:—

1. *Dr. R. C. L. Perkins' Researches on the Colour-Groups of Hawaiian Wasps. By* Professor E. B. Poulton, *F.R.S.*

Dr. Perkins' researches, recorded in 'Fauna Hawaiiensis,' in 'Proc. Ent. Soc., Lond.,' 1912, p. lvi, and 'Trans. Ent. Soc., Lond.,' 1912, p. 677, have thrown a flood of light upon the evolution of colour-groups in one of the most isolated of all the land areas that afford favourable conditions for a fauna and flora. It is probable that the comparatively simple phenomena exhibited in the Sandwich Islands will be found to have a special bearing upon the infinitely more complex conditions found in the most isolated of the inhabited continents.

The only indigenous wasps of the Sandwich Islands belong to the genus *Odynerus* (in the broad sense), and Dr. Perkins concludes that the 102 species have been derived from two original immigrants—a black, yellow-banded species from some unknown direction, and at a much later but still very ancient date, a black, dark-winged species probably from Asia. The latter is extremely dominant, but it found the islands already occupied, and has thus only split up into four species, as against the ninety-eight produced by the original invader.

Dr. Perkins similarly concludes that the fifty-three indigenous bees, all belonging to the genus *Nesoprosopis*, and the eighteen indigenous Fossores (*Crabronidæ*) were derived respectively from a single Asiatic immigrant bee and a si... *gnomon*... Crabronid.
examination ... closely related species of wasps has formed colour-groups
In some cases, thoug... ttracting also many of the species of bees and Fossores.
of economising the ... N.W. island, possesses only one important colour-group—
or attraction ... ged insects with two white or yellow bands. Here the pattern of the earliest immigrant wasp was probably retained, although combined with dark wings, perhaps due to mimicry of the second immigrant. The latter on Kauai has given rise to species with yellow bands.

Oahu, the next island proceeding in a S.E. direction, has four colour-groups, of which two resemble that on Kauai in the possession by some species of pale bands, although fainter than in the N.W. island. Another group containing black, dark-winged insects is probably due to a mimetic approach towards the second original immigrant, a very abundant insect. The fourth group is much marked with red.

On Maui, Molokai, and Lanai there are three groups, one red-marked, one black and dark-winged, and one with pale bands on some of its species.

On the largest island, Hawaii, in the S.E., all the groups tend to fuse into a single large assemblage of black, dark-winged insects.

The species form structural groups of which the members, although obviously closely related, enter different colour-groups in the various islands. In other words, the colour-grouping is entirely independent of zoological affinity.

2. *The Development of Trypanosomes in the Invertebrate Host.* *By* Professor E. A. MINCHIN, *F.R.S.*

If an analysis and comparison be made of those instances in which it can be claimed that the development of a given species of trypanosome in its invertebrate host is known in at least its principal traits, it is seen at once that in every such instance there is a part of the developmental cycle which is constant in occurrence and uniform in character, and another part which is of inconstant occurrence and very variable in character.

In the constant part of the cycle the parasite always assumes the crithidial type of structure and multiplies incessantly in this form to produce a lasting stock of the parasite, certain individuals of which change sporadically from the crithidial into the trypaniform type and so become the final, propagative form of the development, destined to pass back into the vertebrate host and establish the infection in it. During hunger-periods the crithidial forms may pass temporarily, in some cases, into the resting, non-flagellated leishmanial form, until food is again abundant, when they form a new flagellum and revert to the crithidial type of structure.

The inconstant part of the cycle, when it occurs, is intercalated at the very beginning of the development in the invertebrate, and lasts but a relatively short time; it is derived directly from the trypanosomes taken up by the invertebrate from the vertebrate host, and takes the form of an active multiplication of the parasites in either the trypaniform or leishmanial condition. In the cases where this early multiplicative phase is wanting altogether, the trypanosomes taken up by the invertebrate host pass at once into the crithidial phase.

When a further comparison is made between the development of trypanosomes in the invertebrate host and the development of the closely allied species of *Crithidia* and *Leptomonas* which have no alternation of hosts or generations, but are confined during their entire life-history to particular species of invertebrate hosts, it is seen at once that the life-cycles of these parasites of invertebrates are similar in all essential points to the crithidial phases of trypanosomes in their invertebrate hosts. It is evident, therefore, that the crithidial phase in the development of a trypanosome is to be interpreted as a reversion to, or recapitulation of, the type of development that occurred in the ancestral form which was originally a parasite of the invertebrate alone, before it had obtained a footing in the vertebrate host or had acquired the trypanosome-like type of structure; while the multiplicative phases of variable character preceding the crithidial phase in trypanosome-development are to be regarded as having been intercalated secondarily into the life-cycle and of no phylogenetic significance.

3. *A Comparison of the Sizes of the Red Cells of some Vertebrates.* *By* J. BURTON CLELAND, *M.D.*

In searching blood-films from Australian birds for parasites, it was noticed that the red corpuscles of a heron were distinctly larger than those of the various Passerine birds examined. This led to systematic measurements of the sizes of the red cells of various Australian vertebrates. The slides examined have been all stained by 'dry' methods, wet fixation and staining methods being impracticable in the field. Experience shows, however, that this method may be relied on for the purpose in view.

Amongst the fishes, the Dipnoi have enormous red cells, those of *Ceratodus forsteri* being 30 × 23 to 25 μ. The Elasmobranchs have also large cells, varying from 18×12·5 to 23×13·5 μ Amongst Teleostean fishes the size is much smaller. The cells are also rounder. In *Therapion unicolor* they are nearly spherical in size 6 to 8 μ. Other species range from 9×7 up to 13·5×10·3 μ in a catfish.

The reptilia, snakes, lizards, and tortoises have red corpuscles ranging usually from 16 to 21×9 to 11 μ, though in some cases, as in the genus *Hygosoma*, the size tends to be smaller (14 to 16×8 to 10 μ).

Batrachians show red cells usually of from 18 to 20×10 to 14 μ.

Amongst birds, the emu has the largest (15·5 to 16·5×8·5 to 9·5 μ). The Podicipediformes, Sphenisciformes, Ardeiformes, and Pelecaniformes come next (approximately 14×8 μ.) Charadriiformes are generally a little smaller. The pigeons, hawks, parrots, kingfishers, and cuckoos come next, the kingfishers being perhaps the largest of these. In the Passerine birds there is a definite tendency to smaller cells, ranging from 10 to 12×5 to 7 μ, with the exception of the family Corvidæ, where the size approximates more to the previous group.

These figures seem to indicate that with specialisation has eventually come, both in fishes and in birds, a diminution in size of the red cells. The cumbersome corpuscles of *Ceratodus* have doubtless played a part in the gradual extinction of the Dipnoan fishes. The relationship of the various classes to each other is clearly shown in the size of the red cells.

4. *Notes on some Australian Hæmatozoa.*
By J. Burton Cleland, *M.D.*

Owing to the geographical isolation of Australia, the study of the blood parasites of the vertebrates, especially of such as have no easy means of passing over stretches of ocean, is of considerable interest. In some cases, such as the marsupials, interesting speculation arises as to whether the Hæmatozoa found in them reached Australia (1) with the marsupials when these originally came; or (2) as parasites of the invertebrate host by a separate arrival; or (3) whether their appearance represented the adaptation in Australia of a parasite, at one time confined to an invertebrate host, to a habitat partly in the vertebrate and partly in the invertebrate host.

In marsupials Hæmogregarines have been found. Breuil has recorded in a bat the presence of a Trypanosome and of a Plasmodium. In birds, *Plasmodium precox* has been recorded in a falcon, and a Plasmodium has been found in the black swan. Plasmodium has also been recorded in the introduced sparrow. Plasmodium seems to be rare in birds compared with the presence of Halteridium. Halteridia are common in Australian birds, and have been found in all the States with the exception of Tasmania, though they have been found on Flinders Island in Bass Straits. The appearances of the forms found vary somewhat, suggesting specific differences. Trypanosomes have been found in several species, but seem confined more especially to Queensland and northern New South Wales. With the same distribution, and often in the same infected birds, large parasites may be found in distended red cells. The parasite in the red cell is spherical and indents the nucleus of the host-cell, which is stretched over it so as to form a cap. I am of opinion that this is the intracorpuscular form of the Trypanosome with which it is usually associated, although my former colleague, Dr. Harvey Johnston, who was associated with me in first describing this form, has since referred to it as a Leucocytozoon, as does Breinl. The corpuscles are certainly not elongated in the remarkable way in which they are in infections by *Leucocytozoon ziemannii.* Microfilariæ are common in birds.

Reptiles.—Hæmogregarines are common in snakes and lizards. Trypanosomes and Hæmogregarines are met with in tortoises, as well as a Hæmocystidium. A Hæmocystidium has been met with in a gecko, and microfilariæ in the water lizard, *Physignathus lusueurii.*

Amphibia.—A Hæmogregarine has been met with in one species of frog only, Trypanosomes in several species.

Fishes.—Trypanosomes have been found in the freshwater eel and in a catfish.

5. *Adaptation and Inheritance in Silkworms.* By Professor Otto Maas.

The experiments in the feeding of silkworms on the leaves of our well-known vegetable *Scorzonera hispanica*, formerly undertaken by Harz, Tichomiroff, and others, for practical purposes, have been repeated by me on theoretical grounds, as well as by different methods.

As none of the breeds cultivated by Harz's selective method have survived, selection appears not to operate at the length of generations, and consequently the much-vexed question of the heredity of acquired characters cannot be omitted. General constitution, 'Wüchsigkeit,' plays its part as well; qualities are transferred according to now well-known laws of heredity, especially Mendel's, the breeds have to be analysed, in this regard as well, and crossings of normally fed with Scorzonera-fed are to be tried.

Hence the necessity for working on a larger scale, which I began (after some orientating experiments in 1910 and 1911, on the possibility of feeding and selecting some breeds) in 1912. The same material for breeds has to be cultivated in different places, to avoid local failures; different races of silkworms *have to be tried on the same food*, and different feeding on the same race (mulberry, Scorzonera, and half Scorzonera and half mulberry), in order to get a material for suitable crossings, and to produce new possibilities.

In accordance with Kellogg, in spite of all gradations, four main types may be distinguished, of which I used chiefly three (with different eggs, colours, and shape of cocoons and moth-pattern), designated here for convenience with the letters Jap., It., and T., and of these three races different gradations have been applied; for instance, Japanese freshly imported, and Japanese cultivated for years in Europe; Japanese of the wild form (*mandarina*); Italians, whose parents had been fed by myself, 1911, with Scorzonera, and others normal from the sericultural institutions; Tessin normal and with Scorzonera-fed parents, &c. Results of the 1912 feeding are, among others: (1) the It. and T., whose parents had Scorzonera, 1911, did not get well through the same treatment, but died out in spite of every care, in several localities, whereas the freshly imported Jap., It., and the normal T. sustained the new food comparatively well. (2) Still Scorzonera-fed in 1912 held together with mulberry-fed ones of the same race &c. show great differences. A much smaller percentage comes to the respective moultings, much longer time is required (fifty-six days instead of thirty-six). and there is especially a long hesitating and wandering period of the big, well-fed, worm, till it begins to spin. (3) Its cocoon, however, is not inferior, either in size, density, or strength of thread. The crossings of the various breeds show marked differences in their productiveness. The capacity of fertilisation (active and passive) of Scorzonera moths, even of first-rate cocoons, is apparently much inferior (this can be verified not only by general comparison, but also by trying, for instance, the same male with different females and *vice versa*); fecundity, judged by the number of deposited eggs in the same race, is much less; in many cases the females could not fasten their eggs (though that was here not a race character). Also of the fertilised eggs many more decay than in normal egg-deposits, and of the remaining a much smaller number is able to hatch in the next year (*v. infra*).

All these damages are most significant, if both parents are Scorzonera-fed (thus a number of possibilities are at once excluded from further propagation), while in the case where one parent was normally fed the mating could be as fertile as a normal one. In 1912 all possibilities of race-crossings and treatment were tried (a distinction also was made if the male had Scorzonera and the female mulberry or *vice versa*), altogether over thirty, which formed the starting material for 1913.

Of these egg-deposits single ones always have been selected (to work on 'pure lines' for other purposes, of which I shall give an account elsewhere),

but of the remainder a number were always of equal descent regarding race, food in male and female, &c. Those have been united respectively, to form 'populations,' and such populations have been divided and distributed again in 1913 in different localities, and also with different gradations of food, so that last year more than thirty different breeds on different treatments, altogether more than a hundred, have been raised by myself and by my assistants.

In spite of the local dispersion or just on account of its impartiality the result has been very uniform. Almost all the breeds resulting from both Scorzonera-fed parents, even the well hatched, caused much more difficulty in raising with Scorzonera again, died out, or came to spin only in small percentage, while the Scorzonera × mulberry or mulberry × Scorzonera breeds showed a strong advantage and combined, so to say, the 'adaptation' of one parent with the healthy state of the other (still more some of the half-Scorzonera, half-mulberry-fed combinations), and seem to be superior to pure mulberry descendants in strength, and in faculty of going through the Scorzonera treatment to spinning. (That may be valid, of course, only for a certain number of the offspring, which number follows the Mendelian law.)

Whether really 'crossing favours adaptation' can be decided by this year's (1914) breedings; a further gradation prepared by corresponding copulæ of 1913. These copulæ have been tried as much as possible within the same race to avoid confusion, but with the utmost possible variety of Scorzonera handicapping, as the grandparents besides the parents have to be considered.

For instance, I., the 1914 breed, both parents 1913 Scorzonera-fed; (*a*) all four grandparents 1912 Scorzonera-fed; (*b*) both grandparents of one side 1912 Scorzonera-fed, of the other side Scorzonera × mulberry (= three grandparents Scorzonera, one mulberry-fed). Further gradations to male and female: (*c*) grandparents on both sides Scorzonera × mulberry-fed or on one side both grandparents Scorzonera-fed, on the other both mulberry-fed (= two grandparents Scorzonera, two mulberry-fed), but in different combinations; (*d*) grandparents of one side Scorzonera × mulberry, of the other both mulberry-fed (one grandparent Scorzonera, three mulberry-fed); (*e*) different combinations of the half-Scorzonera-mulberry grandparents (*i.e.* fed up to the fourth moulting with Scorzonera, then with mulberry).

II. Of the parents in 1913 one with mulberry (grandparents also mulberry), the other parent with Scorzonera (grandparents various gradations, *vide* I.), &c.

The results of 1914, as far as I can check them at present, have confirmed those of 1912 and 1913, giving corresponding gradations of the crossed and of the pure breeds with regard to their adaptation to the Scorzonera treatment. Of some biological results, the instincts of the young worms to attack and leave different kinds of food, their tropisms, I shall give an account elsewhere, also of some special experiments of inheritance relating to the melanism, called the 'moricund,' to the 'sport' of 'non-spinners,' or abnormal 'atavistic' wing-patterns.

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6. *Notes on Peripatus and on Australian Land Planarians.* *By* T. Steel.

TUESDAY, AUGUST 25.

The following Papers were read:—

1. *Studies on Echinoderm Larvae.* *By* Dr. T. Mortensen.

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2. *On the Worm Parasites of Tropical Queensland.* *By* Dr. W. Nicol.

It is only five years ago since the study of worm parasites was taken up systematically in Australia. Earlier work had been of a desultory nature. In tropical Australia little work was done until the foundation of the Australian Institute of Tropical Medicine; since then a large and representative collection has been made. This paper gives a brief account of that collection.

The most common human parasites are the hook worms (*Ankylostoma* and *Necator*). Other human parasites are not more common than in temperate parts, while hydatids are much rarer than in other parts of Australia. The parasites of domesticated animals have not received much attention and only a few scattered records occur. The most outstanding parasite of the dog is *Dirofilaria immitis*, which infects the heart and lungs and appears to cause much mortality. In rats the characteristic parasite is the large Echinorhynch, *Gigantorhynchus moniliformis*.

The parasites of marsupials and monotremes are interesting. *Filaria* worms are fairly common in wallabies and opossums, while wallabies frequently harbour a large mass of Strongylids in their stomach. The Echidna is frequently infected with tapeworms and a curious little red, spiral-shaped Nematode hitherto undescribed. Similar Nematodes occur in fruit bats and snakes. Not the least interesting mammalian parasite is that described by S. J. Johnston from the dugong, a Trematode which possesses an entirely new type of structure.

The birds do not show many parasites that are peculiarly Australian or tropical. This is probably due to their migratory habits. The reptiles and frogs afford several forms which are typically Australian and a few which appear to be essentially tropical.

It is amongst the fishes that we find the most distinctive parasite fauna. This applies particularly to Trematodes, and it will probably be found that a large proportion of the Australian Trematode parasites of fishes represent new generic types, and in some cases perhaps new family types.

On the migration of Onchourea *larvæ through the capsule of the worm nodule.*

The life-history of the parasitic worm which causes nodular disease in cattle still remains a mystery. A considerable amount of experimental work has been done on the subject, but few positive results have been obtained.

In 1911 T. H. Johnston published a summary of the work which had been done up to that date, and came to the conclusion that the most probable intermediary host is a mosquito, a louse, or a cattle-fly. Since that time four important contributions have been added by Australian workers. The first of these was by Cleland, who made the discovery that some calves which had been reared on Milsom Island, New South Wales, and had never left the island, had become infected with worm nodules. This showed that all the factors concerned in the transmission of the disease are present on the island, and therefore narrows the scope of investigation considerably. Cleland came to the conclusion that a biting fly or a mosquito is the most probable intermediate host.

The second paper is by Gilruth and Sweet, who concluded that fresh infection only occurred in young animals. They showed that direct infection is improbable, and formed the opinion that some biting insect is the most likely transmitter.

On the other hand Breuil performed some experiments which seemed to indicate the possibility of infection by means of water. He was able to induce larvæ to penetrate the unbroken skin and to emerge into water, where they lived a short time. His attempts, however, to infect various aquatic animals with these larvæ were not successful. Quite recently Cleland has published further observations. He found that *Onchocerca* larvæ could be ingested by the stable-fly (*Stomoxys*) and live in it for several days, but he could detect no development in these larvæ. He also discovered free adult worms in cattle, making their way through the tissues of the hind leg from the foot upwards.

It was with the view of confirming Breuil's experiments that the present work was undertaken. The technique employed was similar, but various modifications were adopted to ascertain the effect of temperature, rainfall, &c. In none of the thirty experiments, however, was any positive result obtained.

The procedure consisted in applying sterile water on a calico pad or in a glass vessel to the shaved skin over a nodule, and examining the water a few hours later. The negative results obtained in these experiments show that some factor was lacking which was present in Breuil's investigations.

Further experiments were performed with nodules excised from slaughtered cattle. These nodules were immersed in water under varying conditions for

different lengths of time, and both the water and the nodule were examined thereafter for the presence of larvæ.

The earlier experiments were not very successful, but they showed that a few larvæ could make their escape from the nodule into the water. Later experiments, however, showed that the larvæ could emerge through the worm capsule in large numbers, and fairly continuously for some time after the death of their host.

The effect of acid and alkali was tried, but they did not appear to stimulate the emergence of the larvæ from the nodules. Increase of temperature also was not found favourable.

All the nodules used were carefully examined both before and after the experiments to ensure that no tear or rupture was present in the capsule. Damaged nodules were rejected.

In further experiments of the same nature certain nodules were fixed after varying periods of immersion in water, and thereafter cut into serial sections. In most of the nodules larvæ were found in considerable numbers in the wall of the capsule. Usually they were uniformly distributed in one or more layers, corresponding to the denser strata of the capsule. The impression was received that the water had some definite effect upon the worm mass inside the nodule, stimulating the larvæ to make their escape through the capsule. This effect was not usually produced until after several hours' immersion.

It is worthy of note that the adult worms were found to live for more than two days after removal from this host, and that living larvæ continued to escape from the capsule for at least three days. Attempts to keep the larvæ alive in water were not successful, as they did not survive for more than forty-eight hours at room temperature.

The results of these experiments go to show that *Onchocerca* larvæ can and do make their escape through the capsule of the worm nodule, usually in small numbers, but at times or in some cases in comparatively large numbers. These results do not necessarily support the theory of water-borne infection, but they show that, even if the infection be insect-borne, it is not necessary to suppose, as has been done, that at some period of its life the worm sheds its larvæ into the blood stream. The numbers of larvæ escaping from the nodules are sufficient to ensure a moderate chance of infection in any biting insect. The fact that the larvæ may be induced to penetrate the unbroken skin by the application of water may be merely an accident, but it shows that the larvæ find their way very close to the surface, and may therefore be very readily ingested by any biting insects.

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3. *Joint Discussion with Sections C, E, and K on Past and Present Relations of Antarctica in their Biological, Geographical, and Geological Aspects.*

Sir Douglas Mawson: I propose to deal particularly with recent geographical advances in Antarctica and to lay special stress upon the work which has been performed by the Australasian Expedition. We are now all satisfied that there is a great continent at the southern extremity of the world. Possibly, were the ice to be melted, there would be, not one large land unit, but several. We feel sure, however, that there would be at least one large elevated piece of land in the Australian Quadrant,[1] but there are many who hold that there would be at least a second piece represented by the land south of America, sometimes called West Antarctica. It is, indeed, probable that this latter mass would be found to be split up into a number of small isolated fragments.

South Victoria Land and the Ross Sea Region have been explored or touched upon by eight expeditions, of which several, particularly those of Scott, Shackleton, and Amundsen, have accomplished important land work. In Victoria

[1] For convenience the Antarctic Regions may be considered as divided into four Quadrants, commencing from the meridian of Greenwich, and each named after the lands or seas to the north: hence, African Quadrant, Australian Quadrant, Pacific Quadrant, and American Quadrant.

Land the continent rises to great heights, at least 12,000 or 15,000 feet being visible from the sea. Indeed, Amundsen reports finding mountains up to 19,000 feet in height near the Pole itself. Little was known of the extension of the continent to the west of Victoria Land until recently, when the Australasian Antarctic Expedition visited that region. Two expeditions in 1840, one French and one American, spent a short time in those seas, but neither landed upon the mainland, though the French reached a rocky islet off the coast. They both saw parts of the mainland, but their reports were vague, and served only to stimulate interest in that portion of Antarctica.

The 60 degrees of that portion of Antarctica to which we sailed some three years ago then presented really a virgin field. Now we have brought back the information that it is continuous land, and that it is covered by a very thick and solid ice-cap, which flows out from the central portions of that high continent. In that portion the coast-line is not anything like so steep and precipitous as on the Ross Sea side. The German Expedition of 1901 made the land at what they called Gaussberg, just to the west of the Australian Quadrant. Their ship was frozen into the pack some distance from the land, and they sledged to the latter during the winter, but time did not permit of any extensive land work. The Swedish Expedition in 1901 and several French expeditions since then have done very good work south of America, amplifying the outline already started in that region long ago. A joint British and Swedish Expedition—in the course of preparation—proposes to carry on the work in that locality. The Scottish Expedition of a few years ago sighted the continental ice-sheet at what they called Coats Land, in the Weddell Sea. There it is a steep, straight ice-face—nothing but ice—which rises inland to considerable heights. The German Expedition of 1911, the same period as our own expedition, reached what appears to be the southern extremity of the Weddell Sea, and actually sighted rocky land beyond the ice coast. However, they were prevented from doing any land work. It now remains for future expeditions to tell us exactly what exists south of the Weddell Sea.

Of the African Quadrant practically nothing is known. It has been sighted only in one place—Enderby Land—by a whaler in 1820. Though the discovery of Enderby Land has not since been checked, I feel certain of its existence, after comparing the meteorological conditions logged by Briscoe in that neighbourhood and those met by us off Adelie Land in the same latitude further east. The Pacific Quadrant also is almost a blank, nothing being known excepting King Edward Land on the extreme west.

After surveying the geographical data available we conclude that there is about the South Pole a continent of about 5,000,000 square miles in area. It consists almost entirely of a great ice-cap, rocks seldom out-cropping excepting actually upon the coast.

I will confine my subsequent remarks to the 60° of the Australian Quadrant entered by our own expedition. The voyages of the S.Y. *Aurora* are so numerous that, to save confusion, I shall refer only to the more important. In Macquarie Island, a subantarctic possession of Tasmania in 55° S. lat., we had a party of five stationed for two years, making a complete examination of that fascinating island, and sending up to Australia by wireless regular daily weather messages. Adelie Land was the situation of our main Antarctic base, where eighteen of us wintered and carried out a general scientific and geographical programme for two years. When the wireless was working well, messages were sent up to Australia by relaying through Macquarie Island. About 1,100 miles west of the Main Base station was our western Antarctic base, under the charge of Mr. Frank Wild. The party consisted of eight men all told. As the ship had not been able to reach solid land in that vicinity, on account of solid floe-ice, the party had wintered actually on a floating shell-ice formation—the Shackleton Ice-shelf—seventeen miles from new land, called Queen Mary Land. Between the two Antarctic bases much new land had been met by Captain Davis. In other places the ship sailed over what had been marked as land from vague reports of the early explorers. In 1840 mapping was necessarily rougher than at the present time, but Wilkes particularly exceeded the allowable errors in his charting. I have come to the conclusion that Wilkes's mistakes have arisen from errors of judgment in mistaking solid pack-ice for

land. It is not difficult to fall into such errors, but an appreciation of the possibility of such errors leads one to wait until further proof is obtained before stating that any apparent landfall is actually land. The mirage effects, when looking over pack-ice, are sometimes very misleading. There is no time to deal in detail with the errors discovered in Wilkes's charts. Only in one place, Adelie Land, did we find land where shown on the American charts. In several other places the existence of land was disproved. Elsewhere the ice conditions were adverse, so that we were not able to penetrate as far as Wilkes, with the result that several of his landfalls still call for confirmation. Though Captain Davis was not able to push the ship sufficiently far south to get a view of Knox Land, strong confirmation of its existence is afforded by the data acquired by us on land and sea in that neighbourhood; in fact our soundings show that even if Wilkes's landfalls between Adelie Land and Queen Mary Land be out, the borders of the continent will be found not far to the south.

[Then followed further reference to the work of the Australasian Antarctic Expedition, profusely illustrated by means of lantern slides, some of which were colour-photographs. The points dealt with were the following:—

1. Extensive sledging journeys in Adelie Land, King George Land, and Queen Mary Land; the aggregate of all journeys, including supporting parties, exceeded 4,000 miles.

2. The use made of wireless telegraphy to fix a fundamental meridian in Adelie Land.

3. The continent south of Australia is of the nature of a high plateau, rising to 3,000 feet within twenty miles of the coast, but continuing steadily to rise further to the south. The coasts are, for the most part, of the nature of ice cliffs, where the ice-cap at the water-front still rides on a rocky bottom. Only occasionally do rocky capes break the icy monotony.

4. Floating extensions of the land-ice are met with at intervals, sometimes as tongues from the valley depressions of the borders of the continent, at other times as immense aprons. The most notable of the latter, named the Shackleton Shelf, extends 180 miles from the land.

5. A fringe of rocky or ice-capped islets is a feature of much of the coast.

6. The Continental Shelf is remarkable for its inshore trough: this appears to be a regular feature. As one passes out to sea the water at first deepens, then shoals, before finally plunging down into the ocean depths.

7. The ship's party carried out extensive oceanographic investigations, including a large number of deep-sea soundings.

8. Biological collections were made at each of the three land bases and from the ship; dredgings were made in depths down to 2,000 fathoms. On land the eggs of the Antarctic petrel and of the silver-grey petrel were found for the first time, and several new birds and their eggs were added to the collection. On Macquarie Island a special study was made of sea-elephants.

9. The rocks of Adelie Land and Queen Mary Land proved to be chiefly very ancient gneisses and schists. At Cape Hunter in Adelie Land an ancient sedimentary series, in part phyllites, is to be seen. On the coast of King George Land there extended for many miles rocky cliffs 1,000 feet in height; the upper half is columnar dolerite, below is a sedimentary series containing bands of coal and carbonaceous shales. Woody matter was dredged up at several points along the Antarctic coast. At Macquarie Island the rocks are chiefly igneous—for the most part gabbros. Everywhere the island has been overridden by ice, leaving behind many small glacial lakes and a mantle of till.

10. The simultaneous records obtained by three stations, each about 1,000 miles apart, and all in an entirely new sphere, from which no figures have before been returned, will prove of great value when worked up. The weather conditions at Macquarie Island were 'wirelessed' up to the Commonwealth Weather Bureau every day for two years. During a part of the time it was found possible to do the same from Adelie Land. In Adelie Land the most terrific climate ever recorded was found to prevail. The average wind velocity for the year was found to be 50 miles per hour. It sometimes blew at 90 miles per hour for 24 hours; velocities of over 100 miles per hour were often reached, and on one

occasion 116 miles were recorded in a single hour. When the wind came down in cyclonic gusts it often exceeded a puff velocity of 200 miles per hour. The instrument used for ascertaining the average hourly velocities was the self-recording Robinson cup-anemometer.

11. An unusually extensive magnetic record was obtained, including continuous magnetograph curves at Cape Denison for a period of eighteen months. This station is the nearest yet established to the South Magnetic Pole. A series of careful field determinations were made to within a few miles of the Magnetic Pole. Systematic observations of the Aurora Polaris were made in conjunction with the magnetic and wireless observations.

12. In Adelie Land special account was taken of bacteriology.]

Mr. Griffith Taylor: The present brief account of my work on Captain Scott's Expedition deals with regions near 78° S., extending from Granite Harbour to Mount Discovery.

The walls of all the glacial valleys, as well as the mighty Scarp of Lister, show a series of stages of glacial sculpture which are believed to illustrate a process of evolution. Snow-slopes give rise to *couloirs* which can be seen passing into rounded forms or 'half-funnels' (in Granite Harbour) and so into true cwms (or cirques). In suitable localities (such as below Mt. Lister) headward erosion has changed a cwm into a 'finger valley.' These with other higher cwms tend to form a radiating system resembling the relation of the fingers to the knuckles of a hand.

Great glacial troughs or Trog-taler are well shown in the Ferrar and Taylor Valleys. The latter is free from snow or ice for twenty miles; and it is crossed by several barriers or 'Riegel.'

Examples of erosion by planation arise rarely under present circumstances. Most of the glaciers are comparatively free from débris and their drainage waters are clear instead of milky. Striæ are infrequent. There is much water during summer, as along the Koettlitz Glacier, which is drained by the twenty-mile long Alph River.

The glaciers exert little pressure at their sides, and are usually bounded by a lateral moat, often over a hundred feet deep. Wind, water, and 'freeze and thaw' are potent agents here in carrying off the results of erosion, which is chiefly due to 'freeze and thaw.'

The Riegel (bars) of the Taylor Valley closely resemble those of the European Alps. The largest is 3,000 feet high and almost blocks the Valley where the latter is four miles wide. A narrow defile 1,600 feet deep and about 400 yards wide is cut through its northern end; like the defiles of Bergun, Faido, Mesocco, &c., in the South-East Alps.

The cwm and finger valleys are bounded by steep ridges 1,000 feet high (as at Devil's Bowl and Davis Valley). They could not be cut out by normal glacial erosion; moreover, they are often only a mile or two in length.

It is suggested that the '*palimpsest*' theory welds these two difficulties of Riegel and cwm erosion. The cwm erosion headward cutting occurred first, possibly, along pre-glacial valleys, and cut out finger valleys and steps, which later were overwhelmed by true outlet glaciers flowing out from the Ice Plateau. Thus the Riegel are relics of the old cwm-heads. The basins were excavated by nivation round the slowly receding snouts of almost stagnant glaciers.

The by-gone separation of the Ferrar and Taylor Valleys is described, though now they are apposed in Siamese-twin fashion.

Professor T. W. Edgworth David: In regard to Mr. Taylor's able exposition of cwm erosion, I think he has proved his point, for many of these valleys which have been so deeply recessed into that huge strip of land which may be called the Antarctic 'horst.' I would suggest, however, that we must not press that cwm theory too far. We must expect, and really do find, evidence of transverse faulting in the so-called 'Beacon Sandstone' formation. The Beardmore and the Mackay glacier valleys represent, to my mind, regions of cross faulting and downward slipping which have produced low points in the horst, sagged areas forming in the great rampart of the range low gaps through which the inland-ice has overflowed into Ross Sea. In the case of the main

outlet valleys, I do not think that we should ascribe their whole excavation to the work of cwm glaciers. I do not know whether Mr. Taylor would press for that. These main valleys seem partly tectonic, partly glacial, and very possibly, in their earliest inception, partly fluviatile.

Next, in regard to the Great Ice Barrier, the Ross Barrier—the huge equilateral triangle with sides about five hundred miles in length—is fed by a very large number of glaciers. It has been said by some that it is merely sea-ice thickened by additions of annual snows going on for thousands of years, until at last a thick mass results of sea-ice at the base, while the snows and névés of a thousand or more years form the remainder of its bulk. I would point out that if that were the case, we would surely expect the Ross Barrier to have a pretty even cliff facing the ocean. But we do not find that condition at all; we find it is very variable in height—from twenty feet in some places to a hundred and fifty feet in others. As this thickness is so extremely uneven, it seems to me probable that the Ross Barrier is composed, certainly in its inland portion, and probably in its sea face, of the fanned-out ribs of glacier-ice derived from the contributing glacier valleys which pour into its sides, both from the south-east and from the south-west. I think, then, that this great variability of thickness is proof that there is something more than mere sea-ice and old névé deposits (not but what the latter is an important contributor) helping to form that wonderful ice-mass, which was, perhaps, paralleled by the Pleistocene North Sea ice-sheet of Europe, which impinged upon the shores of Yorkshire, and produced those big lakes near York itself.

Next the question has been raised as to whether the land-mass of Antarctica has been fixed at the South Pole from early geological times, or whether it has migrated. In Cambrian times we know that there was an extensive development of the Archæocyathinæ limestones. These have been described by Mr. Taylor. Quite lately great blocks of Archæocyathinæ limestone, dredged by Dr. W. S. Bruce from depths of about 1,700 fathoms to the north of the Weddell Sea, have been identified as such by Dr. Gordon. There is evidently a great development of these Archæocyathinæ limestones both on the Australian and on the American side of Antarctica. Mr. Taylor has shown that the Archæocyathinæ never extended into the tropical portions of the world, and on the whole were, therefore, probably inhabitants of cool waters. This evidence suggests that the axis of rotation of the earth, so far as the Southern Hemisphere, and probably the Northern Hemisphere too, are concerned, was perhaps approximately where it is now, even as far back as Cambrian time. One cannot, of course, press this statement until a great many more localities for the occurrence of the Archæocyathinæ have been identified. The problem of the occurrence of a Permo-Carboniferous flora within 5° of the South Pole itself will no doubt be touched upon by Professor Seward.

In regard to the possible biological analogue of modern Antarctica with Permo-Carboniferous Australia it may be stated that in Antarctica we find an abundance of the 'sea mats,' a feature which attracted special comment as far back as the date of Sir James C. Ross's Expedition. Similarly, we find that Fenestellidæ are very common in our Permo-Carboniferous beds, both in the Lower and Upper Marine Series, both of which are partly glacial in origin.

In the Antarctic we find a large pecten, *Pecten Colbecki*, enormously abundant in the raised beaches, where it dominates every other form of mollusc. Also in Antarctica we find that sponge spicules are extraordinarily abundant; indeed, the floor of the Ross Sea must be as white as snow with sponge spicules. In the Permo-Carboniferous rocks of N.S. Wales large Aviculopectens are very numerous, and sponge spicules not uncommon.

A point which I wish to emphasise because it is perhaps new, is that in our Permo-Carboniferous rocks we have a widespread development of curious mineral in our marine semi-glacial beds, to which we have given the name of 'glendonite.' This glendonite is associated with glacial erratics; we find it particularly in our Upper Marine Permo-Carboniferous rocks. It is a pseudomorph after glauberite. Sir Thomas H. Holland tells us that, in Lake Sambha in Rajputana, soda sulphates, with a little sodium chloride, are concentrated and thrown out in the water in winter, on account of the sulphates being less soluble in cold water. Mr. H. T. Ferrar, to whom members of the Shackleton

Expedition are very deeply indebted for his valuable work on geological Antarctica, has shown that soda sulphate, mirabilite, now crystallises out in Antarctica, as confirmed by my colleague, R. E. Priestley. It is only in our Permo Carboniferous rocks, where we obtain indications of ice action, that we also find these glendonites: therefore it seems to me that, inasmuch as they were developed in association with glacial erratics, probably the water at that time was very cold.

Next I should like to emphasise the fact that Antarctica is meteorologically a great force centre, and that its presence in the Southern Hemisphere is of the utmost importance to the inhabitants of Australia, not only for the understanding of the past distribution of animals and plants, but particularly from the point of view of meteorology. There can be no question that if Antarctica were wiped off the map now, there would be much less stirring up of the atmosphere in the Southern Hemisphere than there is to-day. There is no doubt that Antarctica acts as a great refrigerator of the atmosphere, causing a steady down-draught, and it is on this account that it is a big factor in Australian meteorology.

In conclusion, may I state that I consider Sir Douglas Mawson has done a great work for science in establishing the meteorological wireless station at Macquarie Island, now taken over by the Federal Government? When one thinks of the great benefit that results from the more accurate weather forecasting made possible by this station, forecasting on the accuracy of which not only so many industries but the very lives of our sailors depend, one feels that all the money expended on Antarctic expeditions, all the hardship and suffering, and even loss of heroic life, that they involve, are justified by the gain to scientific knowledge in the service of humanity.

Professor PENCK: I desire only to make a few remarks as to the geological structure of Antarctica. It seems to me there is a very great difference in the geological structure of the western and eastern parts of Antarctica. Along the Beardmore Glacier there is no trace of mountain-making by folding since the Palæozoic age. On the other hand, the region south of South America has the structure of the Andes, and it has been shown that there are the same rocks in the western part of South America as in western Graham Land, and a very similar section of Mesozoic rocks in Patagonia and in eastern Graham Land. We see in Australia the counterpart of eastern Antarctica. How are these two parts of Antarctica joined together? I think this is still a very open question, and one which offers a wide field for future exploration.

Mr. H. T. FERRAR: Firstly, I would point out that the hill marked J on the 'Discovery' maps is separated from the foot of the Royal Society Scarp by a transverse valley which we called the Snow Valley. On a sledge journey up the Blue Glacier we were able to look along this valley and recognise Mount Kempe standing at its southern end: on a journey to the summit of Brown Island we were able to see into this valley over the tops of the Southern Foothills which have a sharp and definite crest. One of the lantern slides just shown by Mr. Taylor exhibited a long cloud hanging as a festoon along the scarp of the Royal Society Range, and reaching from the northern foot of Mount Kempe up to the western foot of the hill J, which I think betrays the presence of this transverse valley, although its existence is denied by Mr. Taylor. I do not agree with Mr. Taylor that these 'finger-valleys,' as he terms them, head in the corries of the Royal Society Range. I think the ice masses in them are remnants of glaciers which once had their origin on the east face of the Royal Society Range, and then pushed across the transverse valley into McMurdo Sound. The ice-masses have now slipped away from their sources, and are the 'ice-slabs' shown somewhat conventionally on the 'Discovery' maps. The late Dr. Wilson at the south end, and myself at the north end of the Southern Foothills, proved that the ice in these so called finger-valleys does not now meet that shed from the Royal Society Scarp. I think Mr. Taylor journeyed too close in under these foothills to realise that this transverse valley really exists.

Secondly, we had the good fortune to see the Royal Society Range from several points of view, and to us it stood out as an obloid crust-block with a

transverse valley (the Emmanuel Glacier) separating it from the hinterland of this latitude.

Thirdly, the three valleys indicated on the 'Discovery' maps to the northward of the Inland Forts probably have some connection with the Wright and Debenham outlet glaciers mapped by Mr. Taylor's party on their journey to and from Granite Harbour.

With regard to the Great Ice Barrier, I agree with Professor David as to the origin of the ice of the Ross Barrier and other floating Piedmont glaciers, and hold to my view that they are due to the inland-ice draining through the outlet valleys, and crowding upon itself on the coastal platform of the continent.

[The following slides were then exhibited :—

(1) The Admiralty Range, showing fault-block ranges of mountains.

(2) The Beacon Heights, with no suggestion that the Beacon Sandstone on the sides of the Ferrar Glacier was other than a single formation intruded by sills of dolerite.

(3) The Cathedral Rocks (with granite hills in the foreground), showing the rocks in ascending order which go to build up this portion of Antarctica.

(4) The Kukri Hills—a line of junction between schists and gneisses only slightly eroded by a glacier occupying what is probably a fault-trace.

(5) A view of Knob Head Mountain, to explain the movement of the ice of the Ferrar Glacier and of the South West Arm, into Taylor Valley.

(6) The Inland Forts, rasped but hardly eroded by the ice which once passed between them from the Ferrar Glacier over into another drainage system.

(7) The channel between ice and rock at the foot of Knob Head Mountain, showing how spur-truncation is brought about by the agency of water rather than by a rock-charged ice-rasp; also uplift of englacial material where two ice-streams meet.

A map of Antarctica and the Southern Seas was next referred to; the east-west folds of South Africa and Victoria (Australia) were indicated, as was also the submarine furrow between this ridge and that of the Crozets, Kerguelen, &c., and yet another furrow between this island-ridge and the main coast of the Antarctic, and reference was called to the late Dr. J. Milne's view that east-west belts of the earth's crust were more rigid than meridional belts.

Antarctica itself would seem to have been subjected to a torsional stress, which was relieved by rupture along a meridional line now marked by the steep coast of South Victoria Land. That portion embracing Coats Land, Enderby Land, Adelie Land, and South Victoria Land stood firm, while that portion now beneath the Ross Sea and including Edward VII. Land foundered; owing to gain in angular velocity consequent on the earth's rotation it foundered eastward, and slipped round in an easterly direction until retarded by some obstacle near the longitude of Cape Horn. The pressures created by this retardation probably caused the crustal buckle or Andean fold of the Graham Land region.]

Mr. F. Stillwell: At Commonwealth Bay in Adelie Land is a small rocky promontory of about half a square mile in area. Around it were found slight evidences of recent relative uplift. The rock itself was a gneissic granite, which was very fresh and showed very little surface weathering. (Samples on the table indicated the fresh character of the rock at sea-level.) Inland was another exposure of rock which, in contrast to the sea-level rock, showed marked weathering. This inland rock was similar in character to the sea-level rock, and had evidently been exposed a much longer time, and it clearly showed that the sea-level rock had not been exposed sufficiently long to weather. The ice-ablation in the winter months was considerable and amounted to about four inches, and exceeded the summer accretion. It is quite possible then, that Point Denison has been exposed within the last hundred years—a very recent change. From the accounts of the second Base Party, 1,100 miles westwards from Adelie Land, the snow-accretion seemed to be in excess of the snow-ablation. The conditions thus appear to be variable in this quadrant of the Antarctic.

Captain John K. Davis: Much has been said regarding the past and present of Antarctica; I propose to say a few words on future investigation, which will so greatly benefit by the work of those who have gone before. Land

journeys, important as they are, must be supplemented by the investigation of the coast line if we are to progress towards the completion of an outline map of Antarctica. The Antarctic Coast line has been estimated by Professor David at 15,000 miles, only 4,000 of which have been explored; it is high time that a complete circumnavigation of the Continent was undertaken and its outlines correctly laid down upon our maps.

The Australasian Antarctic Expedition under Sir Douglas Mawson may be said to have begun this work of circumnavigation. Sixty degrees of longitude in the Australian Quadrant were investigated by this expedition. When heavy pack made a near approach to the coast impossible, the aid of the sounding machine was invoked, and supplied evidence as to the probable distance of the land. As a result of the voyages of the 'Aurora,' a complete section of the sea-floor between Hobart and the Antarctic is available. This section shows the big rise 200 miles south of Hobart, where the water shoaled over 1,000 fathoms in 50 miles. This rise was traced for a considerable distance on a southerly course (about 125 miles). The least depth found on this ridge was 545 fathoms. Compared with soundings taken in adjacent waters to the east and west, which ranged from 2,700 to 1,670 fathoms, it may be conjectured that the ridge rises at least 10,000 feet above the general level of the sea-floor in the neighbourhood. The bottom for the most part is hard and rocky, but no specimens of the rock were obtained. Further south another smaller rise was indicated—investigation in this locality will probably disclose others. Improved methods, and the experience gained by recent expeditions should enable future explorers to return not only with a map of the lands they have seen, but also with a knowledge of the floor of the ocean over which they have sailed.

The work of the Australasian Antarctic Expedition ended at Gaussberg. From this point another 90° of longitude stretch westward known as the African Quadrant, the most promising field for exploration remaining in the Antarctic.

An interesting feature of the work of the Australasian Antarctic Expedition was that close to the position assigned by Wilkes to Termination Land a huge ice formation (of the same type as the Ross Barrier) extending over 160 miles from the mainland was discovered. The seaward end of this formation was named by us Termination Barrier Tongue, its position is one of considerable interest in view of the unsuccessful attempts of the 'Challenger' and the 'Gauss' to locate Termination Land further west.

Lieut. Wilkes, in his narrative of the voyage of the 'Vincennes' wrote as follows:—'On February 17 (1840) about 10 A.M. we discovered the barrier extending in a line ahead and running north and south as far as the eye could reach [this evidently refers to a line of pack-ice]. Appearances of land were also seen to the south-west, and its trending seemed to be to the northward. We were thus cut off from any further progress to the westward, and obliged to retrace our steps . . . we were now in longitude 97° 37′ E. and latitude 60° 01′ S.' The appearance of land referred to was placed on the published charts of the expedition nearly fifty miles from the position given above and named Termination Land. Allowance being made for the difficulty of obtaining precise longitude in those days, everything points to the fact that Wilkes did sight the great ice-tongue we afterwards rediscovered.

The configuration of the great inlet in the pack-ice as shown on Wilkes's chart, and named Repulse Bay, made it evident to us that some obstruction (either land- or barrier-ice) interfered with the free passage of the pack ice to the west; our subsequent discovery confirmed this belief, and provided the confirmation given as to the accuracy of the work of this courageous pioneer in the locality.

Professor R. N. Rudmose Brown: Professor Penck has referred to the importance of the structure of Antarctica. That, to my mind, is the chief geographical problem to be solved in the Antarctic. There has been speculation as to whether Antarctica is one land mass, or two with a strait between them. It seems to me there is no room for that strait across Antarctica, because of the discoveries by Shackleton and Amundsen of the land bounding the Ross Sea. On the Weddell Sea side discovery has left a gap in the coast line, where there is certainly room for the strait, and yet probabilities are against it.

It is in that region of the Weddell Sea where the doubtful Morrell Land or New South Greenland is placed. Without going into all the evidence regarding Morrell, this much I would like to say, that nobody has ever sailed over the position of Morrell Land, or disproved the position of it since it was first reported. Ross, a very cautious explorer, reported appearance of land about its northern extremity. The Scottish Expedition could not get into that region because of the heavy ice, but the soundings seemed to shelve towards Morrell Land. It is true that Lieut. Filchner reported that he disproved Morrell Land; however, he did not go sufficiently far west to sight it, so his statement is of no value.

The Weddell Sea has been very much neglected. The Ross Sea quarter has had great attention paid to it, probably because it is the nearest and most direct way to the Pole.

Nobody has yet landed on Coats Land, nor on Leopold Land. There was no possibility of landing on the ice-cliff of Coats Land when the 'Scotia' discovered it in 1904; but there was no doubt whatever about that ice-cliff being a part of the ice-cap pouring off the continental land. The deep-sea soundings and deposits by themselves showed that, but what I would like to emphasise is this: that Coats Land seemed to rise in the interior to great heights, but we were not certain of the distance of these heights. Most of us, and particularly those with longer sight and more experience in polar seas, were convinced that this was the plateau rising into the interior to heights of perhaps 10,000 or 15,000 feet. Future exploration will, I believe, confirm this. It is to be hoped that Sir Ernest Shackleton will be enabled to start on his trans-continental expedition, because he will score a new track across Antarctica, and incidentally will solve this problem of the structure of Antarctica towards the Weddell Sea.

Dr. G. C. Simpson: I desire to refer to only one matter connected with the Antarctic. I do not think we realise sufficiently that the southern hemisphere is much colder than the northern hemisphere, and the reason for this difference in temperature is certainly not understood by scientists. When we think of the temperature of a place, we think of the temperature in the lower atmosphere. Now the mere passage of light through the atmosphere will not warm it. The main method in which the atmosphere becomes warmed up is by the sun shining on something it can warm. Now, in the Northern Hemisphere there are large masses of land which can absorb the sun's energy, and then give the heat to the atmosphere. In the Southern Hemisphere, on the contrary, the whole mass of land within the Antarctic continent is covered with ice which is practically a perfect reflector, and therefore when the sun shines on to it a large proportion of the energy is reflected into space. I do not think scientists have quite realised how important that is—that 5,000,000 square miles of the earth's surface in the Southern Hemisphere reflect into space a large part of the energy received from the sun. I feel certain that this is one of the chief reasons for the difference in temperature between the Northern and Southern Hemispheres.

Mr. Charles Hedley: Naturalists have deduced the age, climate, contour, fauna and flora of Tertiary Antarctica from the nature of the Antarctic refugees now living in southern lands. Biologists note that many similar forms, either recent or fossil, are repeated in various southern islands or continents. For instance, there are the monotremes, once perhaps a numerous group, of which two widely different types survive in Australia, Tasmania, and Papua. The bones of other monotremes occur in South American deposits. Then there are the Thylacines, recent in Tasmania, and fossil in South America and Australia. Either we must consider that these groups arose independently in each hemisphere, or that they spread from the one to the other. In the latter case, a South Polar land offered the most direct way from home to home. The simplest explanation of the distribution of marsupials, past and present, is that they originated in South America, spread by way of Archihelenis to Western Europe, by way of the West Indies to North America, and by way of Antarctica to Australasia.

Turning to the Amphibia, both the Hylidæ and the Cystignathidæ have their chief seat in South America; both extend to Australasia, where they

are best developed in the south-east, and gradually vanish before reaching the Moluccas. Here again the most direct road between the two centres lies across Antarctica. By cumulative evidence from plants, both cryptogams and phanerogams, from animals, both vertebrate and invertebrate of many and of varied types, we are led to the conclusion that the way they might have gone was the way they actually went.

A problem which geographers seek to solve is—whether there are now one or two Antarcticas, and again we may ask whether in the Miocene there was one Antarctica or two Antarcticas? If there was only one, why did it not distribute its faunal contents evenly between Australia and New Zealand? But if there were two, or more, did one contribute to the population of New Zealand, and another to that of Australia?

Though the fauna and flora of New Zealand are obviously indebted to Tertiary Antarctica, yet New Zealand has not received any of the vertebrates mentioned; there are neither monotremes, marsupials, Hylidæ, nor Cystignathidæ. Further, the differences are positive as well as negative. In New Zealand there is a group of earthworms, the Acanthodrilids which recur in South America, but not in Tasmania or Australia. The fuchsias, which are mostly South American, have a few outliers in New Zealand, but none in Tasmania; the bushy Veronicas are mostly from New Zealand, but there are a few in South America, and none in Tasmania.

The Antarctic constituent in the Australian flora and fauna includes both a frigid and a subtropical element. How was it that both these incompatible elements could issue from the same source? The answer offered is that then, as now, a high plateau existed in central Antarctica, where the frigid forms had their station, while the subtropical species existed on the coast. While the climate cooled, the land-link between Antarctica and Tasmania endured till the alpines in their turn followed the retreat of the subtropical forms northwards.

The conclusions reached from this comparison of southern flora and fauna are that: (1) at or about the Miocene a subtropical climate prevailed within the Antarctic circle; (2) before, during, or after this warm epoch, land extensions jutted north from Antarctica to New Zealand, to Patagonia and to Tasmania; (3) southern floras and faunas availed themselves of the opportunities for migration offered by these extensions. Relics of these migrations are our only evidence of such changes of land and climate.

Professor A. C. SEWARD gave a brief account, illustrated with lantern slides, of some of the fossil plants collected by members of Captain Scott's second expedition, with special reference to Dr. Wilson's discovery of Glossopteris in latitude 85° South. Fragments of well preserved leaves of *Glossopteris indica* found in the rocks of Buckley Island, a nunatak on the Beardmore glacier, afford important evidence both as to the age of the Beacon Sandstone formation and as to a former connection between Antarctica and Gondwana Land. The geological distribution of Glossopteris in other parts of the world suggests that the strata of the Buckley Nunatak must be assigned to the Permo-Carboniferous period. In addition to Glossopteris, the Polar party found fragments of gymnospermous wood and impure beds of coal. Mr. Priestley, a member of Commander Campbell's party, obtained a large piece of petrified wood from a sandstone boulder on the Priestley glacier in latitude 74° S., which on investigation proved to be a gymnospermous stem of considerable botanical interest; the wood shows well-marked rings of growth and exhibits Araucarian characteristics, but in view of the possession of certain peculiar features it has been described under a new generic name as *Antarcticoxylon Priestleyi*. This stem, though particularly interesting from a botanical point of view and as demonstrating the occurrence of well-grown trees on the Antarctic continent, does not afford any conclusive evidence of geological age. Associated with the partially decayed tissues of Antarcticoxylon was found a winged pollen-grain, described as *Pityosporites* sp., which bears a striking resemblance to the pollen of recent Abietineæ.

In conclusion, reference was made to the bearing of these important discoveries on climatic considerations, and it was pointed out that, while there is

clear evidence of a considerable change in climatic conditions since the period when Glossopteris flourished on the Antarctic continent, there is no adequate reason to assume any change in the position of the earth's axis. Meagre as it is, the material collected by the Polar party calls up a picture of an Antarctic land on which it is reasonable to believe were evolved the elements of a new flora that spread in diverging lines over a Palæozoic continent, the *disjuncta membra* of which have long been added to other land-masses, where are preserved both the relics of the southern flora and of that which had its birth in the north.

The President (Prof. W. BATESON) then declared the discussion closed.

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4. *Heredity of some Emotional Traits.* *By* Professor C. B. DAVENPORT.

While sociologists, who lay great stress on the importance of conditions in determining human traits, have been forced to admit the hereditary basis of feeble-mindedness, they still hold, for the most part, to the view that in the moral field heredity plays little part. Both to test this view and because of the theoretical importance of the subject, the topic of inheritance of the traits of persons of the criminalistic type was undertaken.

The base of the study is the family history of 165 wayward girls in State institutions of the United States. The family histories were secured by specially trained 'field-workers,' operating in conjunction with State Institutions and the Eugenics Record Office. In addition, for the study of special topics a mass of other family histories, some 2,500 in number, was drawn upon freely.

As a general result of these studies about twenty traits were considered in some detail. Many did not yield any clear-cut results; but in at least five cases the hereditary factor was clear and evidently determined the behaviour.

1. The tendency to tantrums—or violent outbursts of temper—in adults is inherited as a dominant trait; that is, it does not skip generations. In several scores of histories it was possible to trace the tendency back three, four, and even five generations.

2. Violent eroticism, or striking lack of self-control in the sex sphere, is also a positive character, and likewise is traced back without breaking generations; and half of the offspring of a highly erotic person show similar irresistible impulses.

3. Impulsions to suicide are accompanied by depressions. In harmony with what has been shown for some types of mania-depression insanity, it appears that this depression is inherited as a recessive or negative character. It ordinarily skips generations; but the tendency is ordinarily found on both sides of the parentage of the affected individual.

4, 5. Two other traits appear, remarkably enough, as sex-linked characters. They are transmitted through mothers to some or all of their sons. They appear in daughters, typically, only when shown by the father, and the tendency is carried also by the mother. If both parents show the trait all children have the tendency to develop, in due time, the trait. These traits are dipsomania and certain other types of irresistible impulsions to drink, and nomadism, or the impulsion to wander.

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5. *The Hormone Theory of the Heredity of Somatic Modifications.* *By* Dr. J. T. CUNNINGHAM, *M.A.*

Darwin's theory of the origin of species was founded on the assumption that species were divided by differences of adaptation. It may be true that allied species sometimes differ slightly in their mode of life, and show differences of structure corresponding to these differences of action; but investigation has entirely failed to prove any utility or bionomical significance for many specific and other diagnostic characters, and the assumption that such characters are due to correlation with adaptive characters is without foundation.

Mendelism in itself throws no direct light on the origin of characters; it deals merely with their transmission. It is inferred, however, by the

Mendelians that characters transmitted as units must have arisen as units, and it is certain that Mendelism has shown how loss of characters and new combinations produce new varieties or types. It is reasonable to conclude from present knowledge that non-useful diagnostic characters have arisen as the result of gametogenesis and conjugation; but the principles of Mendelism or mutation are not applicable to the phenomena of adaptation.

In the first place when we see, as in the frog, the flat-fish, or the caterpillar, adaptation to two quite different sets of conditions in the individual life, it is impossible to believe that such transformation was due to mutations not caused by the external conditions. There is no evidence that the necessary gradual changes could occur unless the conditions produced them; if so, why have they not occurred in other cases when the conditions were absent.

In the second place we have the phenomena of secondary sexual characters, of which one of the most impressive and most fully investigated is that of the antlers of stags. The Mendelian merely regards such characters as mutations which are coupled with primary sex. But primary sex is determined at fertilisation, and such secondary sex characters have been shown to be dependent on the presence and function of the gonads. Characters which are determined in the gametes are not generally affected by computations of gonads at any part of the body in after life. It has been shown that the effects of castration on the development of secondary sexual characters are due to the stimulus of chemical substances produced by the gonads, especially in their functional activity.

No hypothesis explains these facts except the Lamarckian, namely, that the stimuli involved in the use of the organ originally produced them by causing hypertrophy in the part of the soma affected, and that in course of generation the tendency to this hypertrophy was transmitted to the gametes. The hormone theory explains how such transmission may be effected. The hypertrophied part gives off chemical substances or hormones which circulate through the body, and acting on the gametes stimulate those parts of them which are destined to develop the same parts in the next generation. The transmitted effect may be infinitesimal at first, but if continued for many generations would account for the phenomena we now observe.

This, of course, would account for the transmission of all somatic modifications due to external stimuli, and a special application of the theory is needed to explain the peculiarities of functional secondary sexual characters.

In the first place the stimuli in these cases have acted only on individuals of one sex, on the males in stags, on the females in the case of the mammary glands. On any other theory a variation occurring in one sex would be inherited by both sexes unless it was coupled with primary sex, and then it would be wanting in the other sex. But antlers are not wanting in females nor mammary glands in males: they are only not developed. On the hormone theory the somatic modifications were produced at the time when the gonads were giving off their hormones, and thus the tendency which is inherited is to develop these modifications in the presence of those hormones and not otherwise. Then we can understand why the organs develop only at puberty, and often only develop during the period of sexual activity, being shed or absorbed at the end of that period and re-developed.

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6. *Some Facts regarding the Anatomy of the Genus* Pegasus. *By* Professor Hector F. E. Jungersen.

The facts, briefly condensed in the following abstract, have—for the greater part—hitherto been overlooked or unknown.

Cranial Skeleton.—Opisthotics, alisphenoids, orbitosphenoids, and basisphenoid absent; no eye-muscle canal. Posttemporal (suprascapular) forms part of the skull. Three stout infraorbitals, the middle and posterior firmly connected with the preopercle. Opercular apparatus complete. The large flat preopercle, covering most of the lower face of the head, has generally been taken as 'homologous to operculum, præoperculum, and suboperculum' (Günther), while the very small opercle and subopercle, hidden in thick skin, have completely escaped attention. Interoperculum slender, widely separated

from suboperclo, only its anterior end visible from without. The prominent rostrum (much shortened in females of *P. draconis* and *P. volans*) is formed by the coalesced nasals. Pterygo-palatine bar very shortened, consisting of the palatine and only one pterygoid (ento- and metapterygoid wanting), completely separated from hyomandibular suspensorium and connected with anterior end of vomer; together with premaxilla and maxilla lodged in a precranial cavity below the base of the rostrum. Between premaxilla and maxilla is interpolated a large separate bone, corresponding to a small cartilaginous disc or meniscus found in other fishes. Front part of maxilla forming a large process projecting over premaxilla into anterior part of the subrostral chamber. Mandibular suspensorium consisting only of hyomandibular, symplectic and quadrate.—Branchiostegals 5, well developed (hitherto only one observed and described as rudimentary). Basibranchials 2; lower and upper pharyngeals with conical teeth. Hypobranchials I.-III. present; epibranchial IV. very long and stout, widely separated from its ceratobranchial. Pharyngobranchials II. and III. fused into a well-developed dentiferous plate; pharyngobranchials I. and IV. absent.

Clavicular arch consisting only of post temporal and clavicle; part of the latter enters the dermal skeleton of the trunk. *Scapular arch* and *pectoral fin* almost horizontal, their inner faces looking upwards. Foramen scapulare bounded by both scapula and coracoid; the latter with processes fastened to the ventral carapace. Articular face for pectoral rays fixed across a slit in the carapace and made up of part of the scapula and three stout basals.

Pectoral rays unbranched, but fundamentally like soft rays; they are jointed distally, stiff basally, and composed of two longitudinal parts; but owing to the horizontal position of the fin the otherwise lateral constituents in *Pegasus* are upper and lower, and instead of being equal halves, the upper is much more slender than the lower. In the so-called pectoral spines of *P. draconis* and *P. volans* the upper constituent is almost thread-like, imbedded in a furrow along the lower one, which may be extremely stout (*cf.* especially the 5th pectoral ray of *P. volans*); the original jointed condition is much obscured but always observable, and the extreme apex is always soft and distinctly jointed.

Pelvis large (to a certain degree resembling that of *Sebastes*), by means of short ligaments fastened to the clavicles. First ray of *ventral fin* a well-developed, true spinous ray (hitherto completely overlooked); one or two elongated, unbranched soft rays and a slender short one (*Pegasus draconis*, *P. volans*, *P. natans*: 1+2, *P. lancifer* I+3).—*Abdominal vertebræ* 7; the anterior 6 immovably joined, devoid of ribs, provided with large spinous processes forming together a long partition, the upper margin of which (from vertebra 2 to 6) carries a modified interneural, probably representing an aborted first dorsal fin. 7th vertebra movable, provided like the 8th (the first caudal) with strong ribs (probably 'epipleurals' rather than true ribs). Number of caudal vertebræ: *P. draconis* 12, *P. volans* 13, *P. natans* 15.[1] Vertebræ 8-12 connected with 5 dorsal and 5 anal interspinous bones, all bisegmented; first and interspinous bone considerably enlarged. Last caudal vertebra terminating as a vertical plate (probably the urostyle fused with 2 hypurals), 8 caudal, 5 anal, and 5 dorsal soft, unbranched rays.

The *main longitudinal muscles* of the trunk have been modified under the influence of the immovable carapace. The dorsal and ventral portions are separated on each side by a considerable interspace, the lateral body wall consisting only of the dermal armour and its peritoneal lining; besides the anterior, part of the dorsal portion is mainly reduced to a flat thin ligament. In the posterior part of the trunk and in the movable tail the longitudinal muscles are well developed, with strong tendons inserted to the dermal skeleton as well as to the vertebræ.—*Gills* four, each a double row of leaves. *Pseudobranchia* large, with 6-7 leaves.—*Gill-rakers* small, papilliform; a slit in front of lower pharyngeal.—*Air-bladder* absent. The greater part of the contents of the body cavity lodged in front of pelvis. A large left and a small right lobe of the *liver* are connected by a narrow bridge below the alimentary canal; most of the lobes situated dorsally to the latter. The wide *œsophagus* passes into the quite straight and simple *stomach*, which again without any demarcation continues

[1] *P. lancifer* I have not had the opportunity to dissect.

in the intestine, the beginning of the latter only indicated by the entrance of the bile-duct. A gall-bladder on the lower face of the right liver lobe. Behind the entrance of the bile-duct the intestine turns to the *left* side after two convolutions below the left liver-lobe it runs transversely under the liver bridge to the right side, and after two narrow convolutions it reaches the middle line and as the colon passes over the pelvis to the anus.—The *kidneys* are remarkably short, reaching from the skull over only one-third of the body cavity; urinary ducts long, urinary vesicle large, bilobed. *Ovaries* closed sacs behind the kidneys, *oviducts* short and wide. *Testes* short and narrow. The *caudal vein* divides into *two large veins* passing along the urinary duct into the kidneys. The *aorta* follows in the trunk the right side of the vertebræ, giving off the arteria cœliaca far in front, just behind the union of the branchial arteriæ revehentes.

The facts mentioned above clearly show the *Pegasus* (1) to be an Acanthopterygian, (2) to represent at least a 'suborder' of its own, distinguished by several structural peculiarities from all fishes hitherto known (see, for example, the quite unique precranial position of the pterygo-palatine bar together with the premaxilla and maxilla, the connection of the latter bones by means of an interpolated bone, &c.). Possibly the *Pegasidæ* (*Hypostomides*) may be a strongly modified offshoot from the stem of the *Scleroparei*; but no existing mail-cheeked fish shows any closer relationship with the *Pegasidæ*, certainly not forms like *Agonus* or *Aspidophoroides*.

7. *Acquired Habits of Muscidæ (Sheep-Maggot-Flies). By* WALTER W. FROGGATT, *F.L.S.*

At the present time the most serious enemies of the land-owners and squatters in the greater part of pastoral Australia are several species of blow-flies. Forsaking their natural food, chiefly carrion, they have acquired the habit of blowing any soiled or damp wool on otherwise healthy sheep.

All the flies in question, though well-known indigenous species common to the greater part of Australia, only learnt the value of soiled wool as a suitable place to deposit their eggs, or living maggots, within the last ten or twelve years.

Previously they were known merely as 'blow-flies.' Several kinds came into the house and dropped their eggs upon meat, or at times infested open wounds; but otherwise they were simply scavengers. Others were found about decaying animal matter in the vicinity of killing yards or butchers' shops, a few feasted upon rotten fruit and such like fermenting vegetable matter. At the present time (1914) at least four species have been bred in, and identified from, soiled wool taken from sheep running in the paddocks under exactly the same conditions that have prevailed in sheep breeding in Australia for the last twenty-five years.

Though this wool-blowing habit was unknown in this country until about twelve years ago, it is remarkable that in Great Britain, from a very early date in the records of sheep husbandry, two species of 'blue-bottles' or 'blow-flies' have been known to do a certain amount of damage in exactly the same manner to the shepherd's flocks. Though cosmopolitan in its range, *Lucilia sericata*, the common sheep-fly of Great Britain, has never been recorded as having affected healthy sheep in any other part of the world, except in one isolated case, when it was accidentally introduced with sheep into Holland. Prior to 1903 there may have been occasional cases of blown wool, under exceptional circumstances, as has been claimed by sheep-owners, when discussing the question of sheep-maggot-flies, but it was certainly a comparatively rare occurrence to find putrid blown wool. About the end of 1902 the writer first obtained samples of shorn wool containing living maggots; and in the following season they were reported doing considerable damage. Specimens were received for identification from the owners of flocks in the north, north-west, and from a large area of the southern plains.

At first the point of infestation was round the tail where the wool had been soiled with the urine, and the injury was chiefly confined to close-woolled stud ewes. Within a very short time, however, the flies found that other kinds of

damp wool were suitable, and though the sheep with the thickest fleeces and wrinkled skins are the most susceptible, no class or breed of sheep is exempt in a bad fly year. Ewes, too, were the first that suffered, but it was soon evident that both sexes were liable to infestation if weather conditions were favourable and flies abundant. Wethers are blown anywhere if dirty or damp, and lambs after tailing and marking are often so badly blown that a certain percentage die despite the greatest care; while on the large holdings in Central Queensland, where the system of marking is more rough and ready, thousands of lambs, particularly wether lambs, are blown, and in some cases might be said to be eaten alive. Rams, though they often get 'maggoty heads' from the after-results of fighting, were the last to be attacked on the body wool. But it is now quite a common thing to find a number of stud rams badly blown about the crutch, and the maggots swarming on the wool of the rump.

Where sheep are not examined constantly, and get even slightly blown, the infested area soon spreads, as other flies, attracted by the scent, keep on blowing round the evil-smelling heated wool. As these maggots increase in size they work their way down through the fibre of the wool, and, through their presence, cause the wool to become a blackened putrid mass of corruption. Finally the maggots reach the skin, where they set up an inflammation of the cuticle. The broken skin suppurates and the detached wool is torn off, or falls off. Under such conditions the sheep often wanders away from the flock into the scrub, and dies; the more robust ones recover.

In all the first samples of blown wool, whether received from the sheep-owners or taken direct from sheep in the paddocks, the writer only bred one species of blow-fly. This was the common brown and yellow blow-fly (*Calliphora villosa*), found both in the town and country, a carrion-feeder ranging all over Australia. An unusual increase in the numbers of this species was probably due to several causes; in the first instance to the enormous number of dead animals, particularly sheep, that had died during the great drought a few years before, and which, not worth skinning, usually remained covered with decaying skin and wool. This was also the time when hundreds of thousands of poisoned rabbits were festering all over the pastoral holdings—ideal carrion for the blow-flies. The next factor was the production of a new class of merino sheep, to replace the smaller smooth-bodied animals, quite a different type of larger size, closer wool, wrinkled skin, and heavy yoke all through the fine wool, much more easily soiled with urine and excreta.

With the return of the good seasons the supply of carrion vanished, but the blow-flies remained. Some had blown the dead wool, and recognised the smell of fouled wool, and thus *Calliphora villosa* became a sheep-maggot-fly. Within the year numbers of a second species of blow-fly emerged from samples of infested wool which had been sent in from the country, and placed in the breeding jars. Though the maggots were very similar, it was a very distinct species, *Calliphora oceaniæ*, easily distinguished from the first species by its smaller size, and the colouration of the abdominal segments, which, instead of being golden, have the sides blotched with yellow, and the rest deep metallic blue. The range and habits of both species are identical, and as they are frequently found together it is only reasonable to suppose that *Calliphora oceaniæ* learnt the habit of blowing wool from *Calliphora villosa*.

For several years only these two species were found in the larval state among blown wool. Though there were reports from sheep-owners that a third species was infesting the sheep, and that a dark-coloured 'hairy' maggot was busy among the wool in the western country, it was not until late in 1909 that specimens of the third blow-fly, *Calliphora rufifacies*, was obtained direct from blown wool. There was no mistaking this smaller metallic blue and green fly: the parent of the 'hairy maggot.' While both the previous species produce the typical elongate cylindrical maggot, *Calliphora rufifacies* is a shorter thickened larva having each segment ringed with a band of fleshy filaments, which have given it the popular name in the bush of the 'hairy maggot' or 'hairy maggot-fly.' Though now extending its range, until very lately this fly was not found in the coastal districts, but was confined to the inland districts of Australia.

Before *Calliphora rufifacies* learnt the habit of blowing live wool, presumably through the smell of the wool infected by the other two species, it was a carrion-

feeder in the larval state. Now its carrion-breeding habits have made it the most serious pest among all the blow-flies, for at the time when the wool on the sheep is too hot to breed maggots (in midsummer), and the other species are seldom seen, *Calliphora rufifacies* is laying her eggs on dead sheep and any offal found round the tanks and dams, and is thus always on the increase. At the present time (1914) this species seems to have taken the place of the two common house species, and to be responsible for the greater part of the damage, all over the interior, caused by the sheep-maggot-flies.

The last species to attack our sheep, and that only within the last two years, is the introduced British sheep-fly (*Lucilia sericata*), a species that is the common 'green-bottle-fly' about the coastal country. In this case we have the descendants of the introduced British sheep-fly after having lost the peculiar habit of its ancestors, again acquiring the taste from the habit of allied Australian blow-flies.

8. *Australian Trematodes and Cestodes: a Preliminary Study in Zoogeograhy. By* S. J. JOHNSTON, *B.A., D.Sc.*

Practically all the groups of vertebrate animals found living in the various zoogeographical regions of the earth harbour numbers of parasitic worms. The entozoan fauna of one of these classes of vertebrate host in any particular region is constituted by a number of species which are found to be related to others which comprise the entozoan fauna of the *same class* of vertebrate host living in some other region. For instance, the entozoan fauna of marsupials in Australia comprises a number of Cestodes (*e.g.*, species of *Linstowia*) and a number of Trematodes (*e.g.*, species of *Harmostomum*), and the nearest relatives of each of these are found in certain species of *Linstowia* and *Harmostomum* that live parasitic in South American marsupials.

The Trematodes and Cestodes of Australian birds find their nearest relatives in worms living in related birds that inhabit other parts of the world; and the Trematodes and Cestodes of Australian frogs are most closely related to those of frogs in other regions.

The entozoan fauna of the host animals belonging to any particular class of vertebrate may be separated into two divisions:—(1) Those that have been parasitic in these hosts for a very long time—practically from the first appearance of the host-animals, and (2) those that represent more recent acquirements. The members of the former division may be readily recognised by the fact that they have near relatives parasitic in other branches of the same stock, whilst members of the latter division generally have not. The members of each genus (or sometimes of several closely related genera) in the former division, in many cases scattered all over the world, constitute a natural group, and must be looked upon as derived from common ancestors.

These ancestors were parasites of the progenitors of the host-animals in the very early days, when the group was much younger and much more restricted in its distribution than at the present time. A study of the relationships and distribution of the parasites affords some circumstantial evidence of the past movements and paths of dispersal of the host-animals.

9. *On the Emergence of the Nymph of* Anax papuensis *(Burm) from the Egg (Class* Insecta, *Order* Odonata). *By* R. J. TILLYARD, *M.A., F.E.S.*

Previous to hatching, the embryo lies with its head fitting closely under the pedicel or cap of the egg. The eyes are large and blackish, the antennæ lying between them and directed posteriorly. The clypeus, labrum, mandibles, and maxillæ can be clearly seen. The labium appears as a large paired organ directed posteriorly, and reaching well down between the legs. The legs lie directed posteriorly along the outer (ventral) surface of the embryo, except the hind tarsi, which are directed forwards. The hind end of the abdomen is bent round the posterior end of the egg, the ninth and tenth segments, with the cerci, being directed forwards. The mid-gut still encloses a large cylinder of yolk. The tracheal system can be seen, but is devoid of air.

During the three days previous to hatching, the dorsal vessel increases its pulse from about thirty to the minute to between eighty and one hundred. Just before hatching, a cephalic heart appears in the posterior head region. At first small and only pulsating intermittently, it rapidly increases in size. The pressure thus caused forces the pedicel to break away from the egg, whereupon the nymph flows easily and quickly out of the egg-shell. It emerges swathed in an outer skin or sheath, which has been called by Pierre the 'amniotic covering.' This is shown to be a non-cellular chitinous cuticle, not related to the amnion in any way. It represents, in fact, the first moult of the larva. The swathed stage may be termed the pro-nymph.

The pro-nymph stage lasts only a few seconds. The cephalic heart increases enormously, and is seen to consist of two large chambers, an auricle and a ventricle, which pulsate regularly at about thirty beats to the minute, and appears to be pumping liquid, probably blood, into the head. The latter swells quickly up to twice its original size, and thus the pro-nymphal sheath soon splits down the back of the head and thorax, and the young nymph emerges, freeing itself from the sheath by a few convulsive struggles.

The pro-nymphal sheath is seen to be made of very thin transparent chitin, and shows the complete larval form, with head, mouth-parts, and legs easily seen. It ends posteriorly in a sharp spine, which catches in the broken end of the egg, and so forms an anchor during the emergence of the nymph.

The cephalic heart quickly subsides in the free nymph. Meanwhile, a smaller pulsating chamber has appeared between the rectal valves. While the cephalic heart is forcing the blood into the head, this rectal pulsating organ appears to be pumping water into the rectum. As soon as the nymph is free, its pulsations increase to about eighty per minute, and water is violently forced into the rectum, so that the whole beautiful branchial basket is quickly distended and brought into view. Meanwhile, the tracheal system, which, at the time of hatching, only contained air anteriorly to the mid-gut, is seen to be steadily filling with air. The air travels slowly down the dorsal tracheal trunks and gradually fills the numerous branches, finally entering all the tiny tracheoles of the rectal gills. Afterwards, rectal breathing proceeds regularly.

The young nymph is transparent except for the eyes and the dark plug of the mid-gut. It has two sharply pointed cerci, but the superior appendage is only rudimentary. In a few hours the nymph darkens all over to dull green or blackish. It is suggested that the rupture and atrophy of the amnion described by Brandt in the embryology of Odonata is due to the formation of the pro-nymphal sheath or cuticle, which forms a close-fitting and far more effective protection for the embryo, besides allowing for the early beginning of the process of excretion through the formation of a chitinous exoskeleton.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION.—SIR CHARLES P. LUCAS, K.C.B., K.C.M.G.

The President delivered the following Address at Adelaide on Wednesday, August 12:—

Man as a Geographical Agency.

IN an inaugural address to the Royal Scottish Geographical Society on Geography and Statecraft Lord Milner said: 'If I have no right to call myself a geographer, I am at least a firm believer in the value of geographical studies.' I wish to echo these words. I have no expert geographical knowledge, and am wholly unversed in science, but I am emboldened to try and say a few words because of my profound belief in the value of geographical studies. I believe in their value partly on general grounds, and largely because a study of the British Empire leads an Englishman, whether born in England or in Australia, to the inevitable conclusion that statecraft in the past would have been better, if there had been more accurate knowledge of geography. This statement might be illustrated by various anecdotes, some true, not a few apocryphal; but anecdotes do not lend themselves to the advancement of science. I am encouraged, too, to speak because the field of geography is more open to the man in the street than are the sciences more strictly so-called. It is a *graphy*, not a *logy*. Geology is the science of the earth. Geography is a description of the face of the earth and of what is on or under it, a series of pictures with appropriate letterpress and with more or less appropriate morals to adorn the tale.

Taking the earth as it is, geographical discovery has well-nigh reached its limit. The truth, in the words of Addison's hymn, is now 'spread from Pole to Pole,' and recent exploration at the South Pole, with its tale of heroism, will have specially appealed to the citizens of this Southern land, reminding us all that the age of chivalry is not yet past. The city of Adelaide is rich in the record of explorers, and to the list is now added the name of Sir Douglas Mawson. It is not for me to attempt to take measure of his great enterprise, but the scientific results of his work, including the carrying of wireless telegraphy into the Antarctic Continent, illustrate my thesis that man is a geographical agency. Members of the British Association will note with pleasure that he derived backing and inspiration from the Australasian Association for the Advancement of Science. Outside the polar regions coasts are in most cases accurately known. The age of Cook and Flinders is past. Interiors are more or less known. In Africa there is no more room for Livingstones, Spekes, Burtons, Stanleys. In Australia Sir John Forrest is an honoured survival of the exploring age—the age of McDouall Stuart and other heroes of Australian discovery. The old map-makers, in Swift's well-known lines, 'o'er unhabit-[illegible]downs placed elephants for want of towns.' Towns have now taken the [illegible]lephants and of kangaroos. Much, no doubt, still remains to be done. [illegible] will be made far better known; maps will be rectified; many great [illegible] which are in Australia and elsewhere will be, as they are now being, [illegible] [illegible]rveyed; corners of the earth only penetrated now will be swept [illegible] But as we stand to-day, broadly speaking, there are few more [illegible] to conquer. Discovery pure and simple is passing away.

But meanwhile there is one side of geography which is coming more and more to the front, bringing it more than ever within the scope of the British Association for the Advancement of Science. 'Man is the ultimate term in the geographical problem,' said Dr. Scott Keltie some years since at the meeting at Toronto. 'Geography is a description of the earth as it is, in relation to man,' said Sir Clements Markham, long President of the Royal Geographical Society. Geography, I venture to think, is becoming more and more a description of the earth as it is and as it will be under the working hand of man. It is becoming intensive rather than extensive. Geographers have to record, and will more and more have to record, how far man has changed and is changing the face of the earth, to try to predict how far he will change it in the coming centuries. The face of the earth has been unveiled by man. Will the earth save her face in the years before us, and, if she saves her face, will it be taken at face value? How far, for instance, will lines of latitude and longitude continue to have any practical meaning?

Man includes the ordinary man, the settler, the agriculturist; man includes, too, the extraordinary—the scientific man, the inventor, the engineer. 'Man,' says a writer on the subject, 'is truly a geographical agency,' and I ask you to take account of this agency for a few minutes. I do so more especially because one of the chief features of the present day is the rise of the South; and the rise of the South—notably of Australia—is the direct result of human agency, on the one hand transforming the surface of the land, on the other eliminating distance. The old name of Australia, as we all know, was New Holland. The name was well chosen in view of later history, for while no two parts of the world could be more unlike one another than the little corner of Europe known as Holland, or the Netherlands, and the great Southern Continent, in the one and in the other man has been pre-eminently a geographical agency.

The writer who used this phrase, 'Man is a geographical agency,' the American writer, Mr. G. P. Marsh, published his book, 'Man and Nature,' in 1864, and a new edition, entitled 'The Earth as Modified by Human Action,' in 1874. He was mainly concerned with the destructiveness of man in the geographical and climatic changes which he has effected. 'Every plant, every animal,' he writes, 'is a geographical agency, man a destructive, vegetables, and in some cases even wild beasts, restorative powers'; and again: 'It is in general true that the intervention of man has hitherto seemed to ensure the final exhaustion, ruin, and desolation of every province of Nature which he has reduced to his dominion.' The more civilised man has become, he tells us, the more he has destroyed. 'Purely untutored humanity interferes comparatively little with the arrangements of Nature, and the destructive agency of man becomes more and more energetic and unsparing as he advances in civilisation.' In short, in his opinion, 'better fifty years of Cathay than a cycle of Europe.'

He took this gloomy view mainly on account of the mischief done by cutting down forests. Man has wrought this destruction not only with his own hand, but through domesticated animals more destructive than wild beasts, sheep, goats, horned cattle, stunting or killing the young shoots of trees. Writing of Tunisia, Mr. Perkins, the late able Principal of Roseworthy College, says: 'In so far as young trees and shrubs are concerned, the passage of a flock of goats will do quite as much damage as a bush fire.' Mr. Marsh seems to have met a fool in the forest, and it was man; and he found him to be more knave than fool, for man has been, in Mr. Marsh's view, the revolutionary Radical confiscating Nature's vested interests. 'Man,' he says, 'has too long forgotten that the earth was given to him for usufruct alone, not for consumption, still less for profligate waste.' Trees, to his mind, are Conservatives of the best kind. They stand in the way, it is true, but they stop excesses, they moderate the climate, they give shelter against the wind, they store the water, prevent inundations, preserve and enrich the soil. 'The clearing of the woods,' he says, 'has in some cases produced within two or three generations effects as blasting as those generally ascribed to geological convulsions, and has laid waste the face of the earth more hopelessly than if it had been buried by a current of lava or a shower of volcanic sand'; and, once more, where forests have been destroyed, he says, 'The face of the earth is no longer a sponge but a dust-heap.'

The damage done by cutting down trees, and thereby letting loose torrents

which wash away the soil, is or was very marked in the South of France, in Dauphiné, Provence, and the French Alps. With the felling of trees and the pasturing of sheep on the upper edge of the forest—for sheep break the soil and expose the roots—the higher ground has been laid bare. Rainstorms have in consequence swept off the soil, and the floods have devastated the valleys. The mountain-sides have become deserts, and the valleys have been turned into swamps 'When they destroyed the forest,' wrote the great French geographer, Reclus, about thirty years ago, 'they also destroyed the very ground on which it stood'; and then he continues: 'The devastating action of the streams in the French Alps is a very curious phenomenon in the historical point of view, for it explains why so many of the districts of Syria, Greece, Asia Minor, Africa, and Spain have been forsaken by their inhabitants. The men have disappeared along with the trees; the axe of the woodman, no less than the sword of the conqueror, have put an end to, or transplanted, entire populations.' In the latter part of the South African war Sir William Willcocks, skilled in irrigation in Egypt, and subsequently reclaiming Mesopotamia, was brought to South Africa to report upon the possibilities of irrigation there, and in his report dated November 1901 he wrote as follows: 'Seeing in Basutoland the effect of about thirty years of cultivation and more or less intense habitation convinced me of the fact that another country with steep slopes and thin depth of soil, like Palestine, has been almost completely denuded by hundreds of years of cultivation and intense habits. The Palestine which Joshua conquered and which the children of Israel inhabited was in all probability covered over great part of its area by sufficient earth to provide food for a population a hundred times as dense as that which can be supported to-day.' The Scotch geologist, Hugh Miller, again, attributed the formation of the Scotch mosses to the cutting down of timber by Roman soldiers. 'What had been an overturned forest became in the coarse of years a deep morass.'

In past times there have been voices raised in favour of the forests, but they have been voices crying in the desert which man has made. Here is one. The old chronicler Holinshed, who lived in the reign of Queen Elizabeth, noted the amount of timber cut down for house building and in order to increase the area for pasturage. 'Every small occasion in my time,' he writes, 'is enough to cut down a great wood'; and in another passage either he himself or one of his collaborators writes that he would wish to live to see four things reformed in England: 'The want of discipline in the Church, the covetous dealing of most of our merchants in the preferment of commodities of other countries and hindrance of their own, the holding of fairs and markets upon the Sunday to be abolished and referred to the Wednesdays, and that every man in whatever part of the champaine soil enjoyeth forty acres of land and upwards after that rate, either by free deed, copyhold or fee farm, might plant one acre of wood or sow the same with oke mast, hazell, beach, and sufficient provision be made that it be cherished and kept.'

Mr. Marsh seems to have thought that the Old World, and especially the countries which formed the old Roman Empire, had been ruined almost past redemption; and for the beneficent action of man on Nature he looked across the seas. 'Australia and New Zealand,' he writes, 'are perhaps the countries from which we have a right to expect the fullest elucidation of these difficult and disputable problems. Here exist greater facilities and stronger motives for the careful study of the topics in question than have ever been found combined in any other theatre of European colonisation.'

His book was first written half a century ago. He was a pessimist evidently, and pessimists exaggerate even more than optimists, for there is nothing more exhilarating and consoling to ourselves than to predict the worst possible consequences from our neighbours' folly. Further, though it may be true that man became more destructive as he became more civilised, it is also true that the destruction has been wrought directly rather by the unscientific than by the scientific man. If we have not grown less destructive since, at any rate we have shown signs of penitence, and science has come to our aid in the work of reparation. Governments and associations have turned their attention to protecting woodland and reafforesting tracts which have been laid bare. The Touring Club of France, for instance, I am told, have taken up the question of the damage done by destruction of trees by men and sheep in Haute Savoie, and they assist

reclamation by guidance and by grants. In England, under the auspices of Birmingham University and under the Presidency of Sir Oliver Lodge, the Midlands Reafforestation Association is planting the pit mounds and ash quarries of the Black Country with trees which will resist smoke and bad air, alders, willows, poplars; carrying out their work, a report says, under a combination of difficulties not to be found in any other country. Artificial lakes and reservoirs again, such as I shall refer to presently, are being made woodland centres. In most civilised countries nowadays living creatures are to some extent protected, tree planting is encouraged by Arbor days, and reserves are formed for forests, for beasts and birds, the survivors of the wild fauna of the earth. Some lands, such as Greece, as I gather from Mr. Perkins' report, are still being denuded of trees, but as a general rule the human conscience is becoming more and more alive to the immorality and the impolicy of wasting the surface of the earth and what lives upon it, and is even beginning to take stock as to whether the minerals beneath the surface are inexhaustible. Therefore I ask you now to consider man as the lord of creation in the nobler sense of the phrase, as transforming geography, but more as a creative than as a destructive agency.

How far has the agency of man altered, how far is it likely to alter, the surface of the earth, the divisions and boundaries assigned by Nature, the climate, and the production of the different parts of the globe; and, further, how far, when not actually transforming Nature, is human agency giving Nature the go-by? It should be borne in mind that science has effected, and is effecting transformation, partly by applying to old processes far more powerful machinery, partly by introducing new processes altogether; and that, as each new force is brought to light, lands and peoples are to a greater or less extent transformed. The world was laid out afresh by coal and steam. A new readjustment is taking place with the development of water power and oil power. Lands with no coal, but with fine water power or access to oil, are asserting themselves. Oil fuel is prolonging continuous voyages and making coaling stations superfluous. But of necessity it is the earth herself who gives the machinery for altering her own surface. The application of the machinery is contributed by the wit of man.

The surface of the earth consists of land and water. How far has human agency converted water into land or land into water, and how far, without actually transforming land into water and water into land, is it for practical human purposes altering the meaning of land and water as the great geographical divisions? A writer on the Fens of South Lincolnshire has told us: 'The Romans, not content with appropriating land all over the world, added to their territory at home by draining lakes and reclaiming marshes." We can instance another great race which, while appropriating land all over the world, has added to it by reclaiming land from water, fresh or salt. The traveller from Great Britain to the most distant of the great British possessions, New Zealand, will find on landing at Wellington a fine street, Lambton Quay, the foreshore of the old beach, seaward of which now rise many of the city's finest buildings on land reclaimed from the sea; and instances of the kind might be indefinitely multiplied. Now the amount of land taken from water by man has been taken more from fresh water than from sea, and, taken in all, the amount is infinitesimal as compared with the total area of land and water; but it has been very considerable in certain small areas of the earth's surface, and from these small areas have come races of men who have profoundly modified the geography and history of the world. This may be illustrated from the Netherlands and from Great Britain.

Motley, at the beginning of 'The Dutch Republic,' writes of the Netherlands: 'A region, outcast of ocean and earth, wrested at last from both domains their richest treasures.' Napoleon was credited with saying that the Netherlands were a deposit of the Rhine, and the rightful property of him who controlled the sources; and an old writer pronounced that Holland was the gift of the ocean and of the rivers Rhine and Meuse, as Egypt is of the river Nile. The crowning vision of Goethe's Faust is that of a free people on a free soil, won from the sea and kept for human habitation by the daily effort of man. Such has been the story of the Netherlands. The Netherlands, as a home for civilised men, were, and are, the result of reclamation, of dykes and polders.

The kingdom has a constantly changing area of between 12,000 and 13,000 square miles. Mr. Marsh, in his book, set down the total amount gained to agriculture at the time he wrote 'by dyking out the sea and by draining shallow bays and lakes' at some 1,370 square miles, which, he says, was one tenth of the kingdom; at the same time, he estimated that much more had been lost to the sea—something like 2,600 square miles. He writes that there were no important sea dykes before the thirteenth century, and that draining inland lakes did not begin till the fifteenth, when windmills came into use for pumping. In the nineteenth century steam pumps took the place of windmills, science strengthening an already existing process. Between 1815 and 1855, 172 square miles were reclaimed, and this included the Lake of Haarlem, some thirteen miles long by six in breadth, with an area of about seventy-three square miles. This was reclaimed between 1840 and 1853. At the present time, we are told, about forty square miles are being reclaimed annually in Holland; and meanwhile the Dutch Government have in contemplation or in hand a great scheme for draining the Zuyder Zee, which amounts to recovering from the ocean land which was taken by it in historic times at the end of the fourteenth century. The scheme is to be carried out in thirty-three years and is to cost nearly sixteen million pounds. The reclamation is to be effected by an embankment across the mouth of this inland sea over eighteen miles long. The result will be to add 815 square miles of land to the kingdom of the Netherlands, 750 square miles of which will be fertile land, and in addition to create a much-needed freshwater lake with an area of 557 square miles; this lake is to be fed by one of the mouths of the Rhine.

London is partly built on marsh. The part of London where I live, Pimlico, was largely built on piles. A little way north, in the centre of fashion, is Belgrave Square, and here a lady whom I used to know had heard her grandfather say that he had shot snipe. Take the City of London in the strict and narrow sense. The names of Moorfields and Fensbury or Finsbury are familiar to those who know the City. Stow, in his Survey of London, over three hundred years ago, wrote of 'The Moorfield which lieth without the postern called Moorgate. This field of old time was called the Moor. This fen or moor field, stretching from the wall of the city betwixt Bishopsgate and the postern called Cripplegate to Fensbury and to Holywell continued a waste and unprofitable ground a long time.' By 1527, he tells us, it was drained 'into the course of Walbrook, and so into the Thames, and by these degrees was this fen or moor at length made main and hard ground which before, being overgrown with flags, sedges and rushes, served to no use.' It is said that this fen or marsh had come into being since Roman times. The reclamation which has been carried out in the case of London is typical of what has been done in numerous other cases. As man has become more civilised, he has come down from his earlier home in the uplands, has drained the valley swamps, and on the firm land thus created has planted the streets and houses of great cities.

The Romans had a hand in the draining of Romney Marsh in Sussex, and here Nature co-operated with man, just as she has co-operated in the deltas of the great rivers, for the present state of the old Cinque Ports, Rye and Winchelsea, shows how much on this section of the English coast the sea has receded. But the largest reclamation was in East Anglia, where the names of the Fens and the Isle of Ely testify to what the surface once was. 'For some of our fens,' writes Holinshed, 'are well known to be either of ten, twelve, sixteen, twenty or thirty miles in length. . . . Wherein also Elie, the famous isle, standeth, which is seven miles every way, and whereunto there is no access but by three causies.' Arthur Young, in 1799, in his 'General View of the Agriculture of the County of Lincoln,' a copy of which he dedicated to that great friend of Australia, Sir Joseph Banks, who was a Lincolnshire landowner and a keen supporter of reclamation, wrote of the draining which had been carried out in Lincolnshire. 'The quantity of land thus added to the kingdom has been great; fens of water, mud, wild fowl, frogs and agues have been converted to rich pasture and arable worth from 20*s.* to 40*s.* an acre . . . . without going back to very remote periods, there cannot have been less than 150,000 acres drained and improved on an average from 5*s.* an acre to 25*s.*' 150,000 acres is about 234 square miles, but the amount reclaimed by draining in Lincolnshire in the seventeenth, eighteenth and nineteenth centuries seems

to have been well over 500 square miles. The Fenlands as a whole extended into six counties. They were seventy miles in length, from ten to thirty miles broad, and covered an area of from 800 to 1,000 square miles. One estimate I have seen is as high as 1,200 square miles. Mr. Prothero, in his book on 'English Farming, Past and Present,' tells us that they were 'in the seventeenth century a wilderness of bogs, pools and reed shoals—a vast morass from which here and there emerged a few islands of solid earth.' In the seventeenth century a Dutch engineer, Vermuyden, was called in to advise, and the result of draining what was called after the peer who contracted for it the Bedford Level, together with subsequent reclamations, was to convert into ploughland and pasture large tracts which, in the words of an old writer, Dugdale, had been 'a vast and deep fen, affording little benefit to the realm other than fish or fowl, with overmuch harbour to a rude and almost barbarous sort of lazy and beggarly people.' In Lincolnshire there was a district called Holland, and in Norfolk one called Marshland, said to have been drained by, to quote Dugdale again, 'those active and industrious people, the Romans.'

The Dutch and the English, who thus added to their home lands by reclamation, went far and wide through the world, changing its face as they went. The Dutch, where they planted themselves, planted trees also; and when they came to land like their own Netherlands, again they reclaimed and empoldered. The foreshore of British Guiana, with its canals and sea defences, dating from Dutch times, is now the chief sugar-producing area in the British West Indies. If again in Australia man has been a geographical agency, he learnt his trade when he was changing the face of his old home in the British Isles.

Instances of reclaiming land from water might be indefinitely multiplied. We might compare the work done by different nations. In Norway, for instance, Reclus wrote that 'the agriculturists are now reclaiming every year forty square miles of the marshes and fiords.' Miss Semple, who, in the 'Influences of Geographic Environment,' writes that 'between the Elbe and Scheldt' (that is, including with the Netherlands some of North Germany) 'more than 2,000 square miles have been reclaimed from river and sea in the past 300 years,' tells us also that 'the most gigantic dyke system in the world is that of the Hoangho, by which a territory of the size of England is won from the water for cultivation.' Or we might take the different objects which have impelled men here and there to dry up water and bank out sea. Agriculture has not been the only object, nor yet reclaiming for town sites. Thus, in order to work the hematite iron mines at Hodbarrow, in Cumberland, an area of 170 acres was, in the years 1900-04, reclaimed from the sea by a barrier over $1\frac{1}{4}$ mile long, designed by the great firm of marine engineers, Coode and Matthews, who built the Colombo breakwater. The reclaimed land, owing to the subsidence caused by the workings, is now much below the level of the sea. Here is an instance of reclamation not adding to agricultural or pastoral area, but giving mineral wealth, thereby attracting population and enriching a district.

How far has land been drowned by the agency of man? Again the total area is a negligible quantity, but again, relatively to small areas, it has been appreciable, and the indirect effects have been great. God made the country, man made the town; and the town is trying to unmake or to remake the country. The necessities of town life are responsible for new lakes and rivers. Such are the great reservoirs and aqueducts by which water is being brought to New York from the Catskill Mountains, one of the reservoirs being twelve miles long with a water surface of nearly thirteen square miles. The whole work has been described by a writer in the *Times* as 'hardly second in magnitude and importance to the Panama Canal.' In Great Britain cities in search of a water supply have ordered houses, churches, fields to be drowned, and small lakes to come into existence. Liverpool created Lake Vyrnwy in Montgomeryshire, with a length of nearly five miles and an area of 1,121 acres. Birmingham is the parent of similar lakes in a wild Radnorshire valley near my old home. The water is not carried for anything like the distance from Mundaring to Kalgoorlie, and on a much greater scale than these little lakes in Wales is the reservoir now being formed in New South Wales by the Burrinjuck dam, on the Murrumbidgee River, which, as I read, is, or will be, forty-one miles long, and cover an area of twenty square miles. If I under-

stand right, in this case, by constructing a giant dam over 200 feet high across a gorge through which the river flows, a long man-made lake has been or is being called into existence. A still larger volume of water is gathered by the great Assouan dam, which holds up the Nile at the head of the First Cataract, washing, and at times submerging, the old temples on the Island of Philæ in mid-stream. First completed in 1902, the dam was enlarged and heightened by 1912; and the result of the dam is at the time of high Nile to create a lake of some 65 square miles in area, as well as to fill up the channel of the river for many miles up stream. Illustrations of artificial lakes might be multiplied from irrigation works in India. An official report on the State of Hyderabad, written some years ago, has the following reference to the tanks in the granitic country of that State: 'There are no natural lakes, but from the earliest times advantage has been taken of the undulating character of the country to dam up some low ground or gorge between two hills, above which the drainage of a large area is collected. Such artificial reservoirs are peculiar to the granitic country, and wherever groups of granite hills occur tanks are sure to be found associated with them.' Take again the great ship canals. The Suez Canal runs for 100 miles from sea to sea, though for part of its course it runs through water, not through sand. It is constantly growing in depth and width. Its original depth was 26¼ feet; it is now, for nine-tenths of its length, over 36 feet, and the canal is to be further deepened generally to over 39 feet. Its original width at the bottom was 72 feet: it is now, for most of its course, over 147 feet; in other words, the width has been more than doubled. A writer in the *Times* on the wonderful Panama Canal said: 'The locks and the Gatun dam have entailed a far larger displacement of the earth's surface than has ever been attempted by the hand of man in so limited a space.' Outside the locks the depth is 45 feet, and the minimum bottom width 300 feet. The official handbook of the Panama Canal says: 'It is a lake canal as well as a lock canal, its dominating feature being Gatun Lake, a great body of water covering about 164 square miles.' The canal is only fifty miles long from open sea to open sea, from shore line to shore line only forty. But, in making it, man, the geographical agency, has blocked the waters of a river, the Chagres river, by building up a ridge which connects the two lines of hills between which the river flows, this ridge being a dam 1½ miles long, nearly half a mile wide at its base, and rising to 105 feet above sea-level, with the result that a lake has come into existence which is three quarters of the size of the Lake of Geneva, and extends beyond the limits of the Canal zone. When all the sluices are open, a greater volume of water passes through them than comes over the Falls of Niagara.

Mr. Marsh, in his book, referred to far more colossal schemes for turning land into water, such as flooding the African Sahara or cutting a canal from the Mediterranean to the Jordan and thus submerging the basin of the Dead Sea, which is below the level of the ocean. The effect of the latter scheme, he estimated, would be to add from 2,000 to 3,000 square miles to the fluid surface of Syria. All that can be said is that the wild-cat schemes of one century often become the domesticated possibilities of the next and the accomplished facts of the third; that the more discovery of new lands passes out of sight the more men's energies and imagination will be concentrated upon developing and altering what is in their keeping; and that, judging from the past, no unscientific man can safely set any limit whatever to the future achievements of science.

But now, given that the proportion of land to water and water to land has not been, and assuming that it will not be, appreciably altered, has water, for practical purposes, encroached on land, or land on water? In many cases water transport has encroached on land transport. The great isthmus canals are an obvious instance; so are the great Canadian canals. The tonnage passing through the locks of the Sault St. Marie is greater than that which is carried through the Suez Canal. Waterways are made where there was dry land, and more often existing inland waterways are converted into sea-going ways. Manchester has become a seaport through its Ship Canal. The Clyde, in Mr. Vernon Harcourt's words, written in 1895, has been 'converted from an insignificant stream into a deep navigable river capable of giving access to ocean-going vessels of large draught up to Glasgow.' In 1758 the Clyde at low water

at Glasgow was only 15 inches deep, and till 1818 no seagoing vessels came up to Glasgow. In 1895 the depth at low water was from 17 to 20 feet, and steamers with a maximum draught of 25½ feet could go up to Glasgow. This was the result of dredging, deepening and widening the river, and increasing the tidal flow. The record of the Tyne has been similar. The effect of dredging the Tyne was that in 1895—I quote Mr. Harcourt again—'Between Shields and Newcastle, where formerly steamers of only 3 to 4 feet draught used to ground for hours, there is now a depth of 20 feet throughout at the lowest tides.' It is because engineers have artificially improved Nature's work on the Clyde and the Tyne that these rivers have become homes of shipbuilding for the whole world. Building training walls on the Seine placed Rouen, seventy-eight miles up the river, high among the seaports of France. The Elbe and the Rhine, the giant rivers Mississippi and St. Lawrence, and many other rivers, have, as we all know, been wonderfully transformed by the hand of the engineer.

But land in turn, in this matter of transport, has encroached upon sea. In old days, when roads were few and bad, when there were no railways, and when ships were small, it was all-important to bring goods by water at all parts as far inland as possible. In England there were numerous flourishing little ports in all the estuaries and up the rivers, which, under modern conditions, have decayed. No one now thinks of Canterbury and Winchester in connection with seaborne traffic; but Mr. Belloc, in 'The Old Road,' a description of the historical Pilgrims' Way from Winchester to Canterbury, points out how these two old-world cathedral cities took their origin and derived their importance from the fact that each of them, Canterbury in particular, was within easy reach of the coast, where a crossing from France would be made: each on a river—in the case of Canterbury on the Stour just above the end of the tideway. In the days when the Island of Thanet was really an island, separated from the rest of Kent by an arm of the sea, and when the present insignificant river Stour was, in the words of the historian J. R. Green, 'a wide and navigable estuary,' Canterbury was a focus to which the merchandise of six Kentish seaports was brought, to pass on inland; it was in effect practically a seaport. Now merchandise, except purely local traffic, comes to a few large ports only, and is carried direct by rail to great distant inland centres. Reclus wrote that bays are constantly losing in comparative importance as the inland ways of rapid communication increase; that, in all countries intersected with railways, indentations in the coast-line have become rather an obstacle than an advantage; and that maritime commerce tends more and more to take for its starting-place ports situated at the end of a peninsula. He argues, in short, that traffic goes on land as far out to sea as possible instead of being brought by water as far inland as possible. He clearly overstated the case, but my contention is that, for human purposes, the coast-line, though the same on the map, has practically been altered by human agency. By the aid of science ports have been brought to men as much as men to ports. We see before our eyes the process going on of bridging India to Ceylon so as to carry goods and passengers as far by land as possible, and in Ceylon we see the great natural harbour of Trincomalee practically deserted and a wonderful artificial harbour created at the centre of population, Colombo.

But let us carry the argument a little further. Great Britain is an island. Unless there is some great convulsion of Nature, to all time the Straits of Dover will separate it from the continent of Europe. Yet we have at this moment a renewal of the scheme for a Channel tunnel, and at this moment men are flying from England to France and France to England. Suppose the Channel tunnel to be made; suppose flying to be improved—and it is improving every day—what will become of the island? What will become of the sea? They will be there and will be shown on the map, but to all human intents and purposes the geography will be changed. The sea will no longer be a barrier, it will no longer be the only high-road from England to France. There will be going to and fro on or in dry land, and going to and fro neither on land nor on sea. Suppose this science of aviation to make great strides, and heavy loads to be carried in the air, what will become of the ports, and what will become of sea-going peoples? The ports will be there, appearing as now on the map, but Birmingham goods will be shipped at Birmingham for foreign parts, and

Lithgow will export mineral direct, saying good-bye to the Blue Mountains and even to Sydney Harbour.

Now, in saying this I may well be told by my scientific colleagues that it is all very well as a pretty piece of fooling, but that it is not business. I say it as an unscientific man with a profound belief in the unbounded possibilities of science. How long is it since it was an axiom that, as a lump of iron sinks in water, a ship made of iron could not possibly float? Is it fatuous to contemplate that the conquest of the air, which is now beginning, will make it a highway for commercial purposes? We have aeroplanes already which settle on the water and rise again; we are following on the track of the gulls which we wonder at in the limitless waste of ocean. A century and a half ago the great Edmund Burke ridiculed the idea of representatives of the old North American colonies sitting in the Imperial Parliament; he spoke of any such scheme as fighting with Nature and conquering the order of Providence; he took the distance, the time which would be involved—six weeks from the present United States to London. If anyone had told him that what is happening now through the applied forces of science might happen, he would have called his informant a madman. Men think in years, or at most in lifetimes; they ought sometimes to think in centuries. I believe in Reclus's words. 'All man has hitherto done is a trifle in comparison with what he will be able to effect in future.' Science is like a woman. She says No again and again but she means Yes in the end.

In dealing with land and water I have touched upon natural divisions and natural boundaries, which are one of the provinces of geography. Flying gives the go-by to all natural divisions and boundaries, even the sea; but let us come down to the earth. Isthmuses are natural divisions between seas; the ship canals cut them and link the seas the canal through the Isthmus of Corinth, the canal which cuts the Isthmus of Perekop between the Crimea and the mainland of Russia, the Baltic Canal, the Suez Canal, the Panama Canal. The Suez Canal, it will be noted, though not such a wonderful feat as the Panama Canal, is more important from a geographical point of view, in that an open cut has been made from sea to sea without necessity for locks, which surmount the land barrier but more or less leave it standing. Inland, what are natural divisions? Mountains, forests, deserts, and, to some extent, rivers. Take mountains 'High, massive mountain systems,' writes Miss Semple, 'present the most effective barriers which man meets on the land surface of the earth.' But are the Rocky Mountains, for instance, boundaries, dividing lines, to anything like the extent that they were now that railways go through and over them, carrying hundreds of human beings back and fore day by day? On what terms did British Columbia join the Dominion of Canada? That the natural barrier between them should be pierced by the railway. Take the Alps. The canton Ticino, running down to Lake Maggiore, is politically in Switzerland; it is wholly on the southern side of the Alps. Is not the position entirely changed by the St. Gothard tunnel, running from Swiss territory into Swiss territory on either side of the mountains?

If, in the Bible language, it requires faith to remove mountains, it is not wholly so with other natural boundaries. Forests were, in old days, very real natural dividing-lines. They were so in England, as in our own day they have been in Central Africa. Between forty and fifty years ago, in his 'Historical Maps of England,' Professor C. H. Pearson, whose name is well known and honoured in Australia, laid down that England was settled from east and west, because over against Gaul were heavy woods, greater barriers than the sea. Kent was cut off from Central England by the Andred Weald, said to have been, in King Alfred's time, 120 miles long and 30 broad. Here are Professor Pearson's words: 'The axe of the woodman clearing away the forests, the labour of nameless generations reclaiming the fringes of the fens or making their islands habitable, have gradually transformed England into one country, inhabited by one people. But the early influences of the woods and fens are to isolate and divide.' Thus the cutting down of trees is sometimes a good, not an evil, and there are some natural boundaries which man can wholly obliterate.

Can the same be said of deserts? They can certainly be pierced, like isthmuses and like mountains. The Australian desert is a natural division

between Western and South Australia. The desert will be there for many a long day after the transcontinental railway has been finished, but will it be, in anything like the same sense as before, a barrier placed by Nature and respected by man? Nor do railways end with simply giving continuous communication, except when they are in tunnels. As we all know, if population is available, they bring in their train development of the land through which they pass. Are these deserts of the earth always going to remain, in Shakespeare's words, 'deserts idle'? Is man going to obliterate them? In the days to come, will the desert rejoice and blossom as the rose? What will dry farming and what will afforestation have to say? In the evidence taken in Australia by the Dominions Royal Commission, the Commissioner for Irrigation in New South Wales tells us that 'the dry farming areas are carried out westward into what are regarded as arid lands every year,' and that, in his opinion, 'we are merely on the fringe of dry farming' in Australia. A book has lately been published entitled 'The Conquest of the Desert.' The writer, Dr. Macdonald, deals with the Kalahari Desert in South Africa, which he knows well, and for the conquest of the desert he lays down that three things are essential—population, conservation, and afforestation. He points out in words which might have been embodied in Mr. Marsh's book, how the desert zone has advanced through the reckless cutting of trees, and how it can be flung back again by tree barriers to the sand dunes. By conservation he means the system of dry farming so successful in the United States of America, which preserves the moisture in the soil and makes the desert produce fine crops of durum wheat without a drop of rain falling upon it from seedtime to harvest, and he addresses his book 'to the million settlers of to morrow upon the dry and desert lands of South Africa.' If the settlers come, he holds that the agency of man, tree-planting, ploughing and harrowing the soil, will drive back and kill out the desert. The effect of tree-planting in arresting the sand dunes and reclaiming desert has been very marked in the Landes of Gascony. Here, I gather from Mr. Perkins' report, are some 3600 square miles of sandy waste, more than half of which had, as far back as 1882, been converted into forest land, planted mainly with maritime pines.

What, again, will irrigation have to say to the deserts? Irrigation, whether from underground or from overground waters, has already changed the face of the earth, and as the years go on, as knowledge grows and wisdom, must inevitably change it more and more. I read of underground waters in the Kalahari. I read of them too in the Libyan Desert. In the 'Geographical Journal' for 1902 it is stated that at that date nearly 22,000 square miles in the Algerian Sahara had been reclaimed with water from artesian wells. What artesian and sub-artesian water has done for Australia you all know. If it is not so much available for agricultural purposes, it has enabled flocks and herds to live and thrive in what would be otherwise arid areas. Professor Gregory, Mr. Gibbons Cox, and others have written on this subject with expert knowledge; evidence has been collected and published by the Dominions Royal Commission, but I must leave to more learned and more controversial men than I am to discuss whether the supplies are plutonic or meteoric, and how far in this matter you are living on your capital.

If we turn to irrigation from overground waters, I hesitate to take illustrations from Australia, because my theme is the blotting out of the desert; and most of the Australian lands which are being irrigated from rivers, and made scenes of closer settlement, would be libelled if classed as desert. Mr. Elwood Mead told the Royal Commission that the State irrigation works in Victoria, already completed or in process of construction, can irrigate over 600 square miles, and that, if the whole water supply of the State were utilised, more like 6000 square miles might be irrigated. The Burrinjuck scheme in New South Wales will irrigate in the first instance not far short of 500 square miles, but may eventually be made available for six times that area. If we turn to irrigation works in India, it appears from the second edition of Mr. Buckley's work on the subject, published in 1905, that one canal system alone, that of the Chenab in the Punjab, had, to quote his words, turned 'some two million acres of wilderness (over 3000 square miles) into sheets of luxuriant crops.' 'Before the construction of the canal,' he writes, 'it was almost entirely waste, with an extremely small population, which was mostly nomad. Some portion of the country was wooded with jungle trees, some was covered with small scrub

camel thorn, and large tracts were absolutely bare, producing only on occasions a brilliant mirage of unbounded sheets of fictitious water.' The Chenab irrigation works have provided for more than a million of human beings; and, taking the whole of India, the Irrigation Commission of 1901-3 estimated that the amount of irrigated land at that date was 68,750 square miles; in other words, a considerably larger area than England and Wales. Sir William Willcocks has been reclaiming the delta of the Euphrates and Tigris. The area is given as nearly 19,000 square miles, and it is described as about two-thirds desert and one-third freshwater swamp. Over 4000 square miles of the Gezireh Plain, between the Blue and the White Nile, are about to be reclaimed, mainly for cotton cultivation, by constructing a dam on the Blue Nile at Sennaar and cutting a canal 100 miles long which, if I understand right, will join the White Nile, thirty miles south of Khartoum.

With the advance of science, with the growing pressure of population on the surface of the earth, forcing on reclamation as a necessity for life, is it too much to contemplate that human agency in the coming time will largely obliterate the deserts which now appear on our maps? It is for the young peoples of the British Empire to take a lead in—to quote a phrase from Lord Durham's great report—'the war with the wilderness,' and the great feat of carrying water for 350 miles to Kalgoorlie, in the very heart of the wilderness, shows that Australians are second to none in the ranks of this war.

It is a commonplace that rivers do not make good boundaries because they are easy to cross by boat or bridge. Pascal says of them that they are 'des chemins qui marchent' (roads that move), and we have seen how these roads have been and are being improved by man. 'Rivers unite,' says Miss Semple; and again, 'Rivers may serve as political lines of demarcation, and therefore fix political frontiers, but they can never take the place of natural boundaries.' All the same, in old times at any rate, rivers were very appreciable dividing-lines, and when you get back to something like barbarism, that is to say in time of war, it is realised how powerful a barrier is a river. Taking, then, rivers as in some sort natural boundaries, or treating them only as political boundaries, the point which I wish to emphasise is that they are becoming boundaries which, with modern scientific appliances, may be shifted at the will of man. In the days to come the diversion of rivers may become the diversion of a new race of despotic rulers with infinitely greater power to carry out their will or their whim than the Pharaohs possessed when they built the Pyramids. You in Australia know how thorny a question is that of the control of the Murray and its tributaries. There are Waterways Conventions between Canada and the United States. Security for the head-waters of the Nile was, and is, a prime necessity for the Sudan and Egypt. The Euphrates is being turned from one channel into another. What infinite possibilities of political and geographical complications does man's growing control over the flow of rivers present!

Thus I have given you four kinds of barriers or divisions set by Nature upon the face of the earth—mountains, forests, deserts, rivers. The first, the mountains, man cannot remove, but he can and he does go through them to save the trouble and difficulty of going over them. The second, the forests, he has largely cleared away altogether. The third, the deserts, he is beginning to treat like the forests. The fourth, the rivers, he is beginning to shift when it suits his purpose and to regulate their flow at will.

I turn to climates. Climates are hot or cold, wet or dry, healthy or unhealthy. Here our old friends the trees have much to say. Climates beyond dispute become at once hotter and colder when trees have been cut down and the face of the earth has been laid bare; they become drier or moister according as trees are destroyed or trees are planted and hold the moisture; the cutting and planting of timber affects either one way or the other the health of a district. The tilling of the soil modifies the climate. This has been the case, according to general opinion, in the North-West of Canada, though I have not been able to secure any official statistics on the subject. In winter time broken or ploughed land does not hold the snow and ice to the same extent as the unbroken surface of the prairie; on the other hand, it is more retentive at once of moisture and of the rays of the sun. The result is that the wheat zone has moved further north, and that the intervention of man has, at any rate for agricultural purposes, made the climate of the great Canadian North-West

perceptibly more favourable than it was. In Lord Strathcona's view, there was some change even before the settlers came in, as soon as the rails and telegraph lines of the Canadian Pacific Railway were laid. He told me that in carrying the line across a desert belt it was found that, within measurable distance of the rail and the telegraph line, there was a distinct increase of dew and moisture. I must leave it to men of science to say whether this was the result of some electrical or other force, or whether what was observed was due simply to a wet cycle coinciding with the laying of the rails and the erection of the wires. I am told that it is probably a coincidence of this kind which accounts for the fact that in the neighbourhood of the Assouan dam there is at present a small annual rainfall, whereas in past years the locality was rainless. Reference has already been made to the effect of cultivation in the Kalahari Desert in increasing the storage of moisture in the soil. But it is when we come to the division between healthy and unhealthy climates that the effect of science upon climate is most clearly seen. The great researches of Ross, Manson, Bruce, and many other men of science, British and foreign alike, who have traced malaria and yellow fever back to the mosquito, and assured the prevention and gradual extirpation of tropical diseases, bid fair to revolutionise climatic control. Note, however, that in our penitent desire to preserve the wild fauna of the earth we are also establishing preserves for mosquitos, trypanosomes and the tsetse fly.

Nowhere have the triumphs of medical science been more conspicuous than where engineers have performed their greatest feats. De Lesseps decided that Ismailia should be the headquarters of the Suez Canal, but the prevalence of malaria made it necessary to transfer the headquarters to Port Said. In 1886 there were 2300 cases of malaria at Ismailia; in 1900 almost exactly the same number. In 1901 Sir Ronald Ross was called in to advise; in 1906 there were no fresh cases, and malaria has been stamped out. Lesseps' attempt to construct the Panama Canal was defeated largely, if not mainly, by the frightful death-rate among the labourers; 50,000 lives are said to have been lost, the result of malaria and yellow fever. When the Americans took up the enterprise they started with sending in doctors and sanitary experts, and the result of splendid medical skill and sanitary administration was that malaria and yellow fever were practically killed out. The Panama Canal is a glorious creation of medical as well as of engineering science, and this change of climate has been mainly due to reclamation of pools and swamps, and to cutting down bush, for even the virtuous trees, under some conditions, conduce to malaria. Man is a geographical agency, and in no respect more than in the effect of his handiwork on climate, for climate determines products, human and others. Science is deciding that animal pests shall be extirpated in the tropics, and that there shall be no climates which shall be barred to white men on the ground of danger of infection from tropical diseases.

If we turn to products, it is almost superfluous to give illustrations of the changes wrought by man. As the incoming white man has in many places supplanted the coloured aboriginal, so the plants and the living creatures brought in by the white man have in many cases, as you know well, ousted the flora and fauna of the soil. Here is one well-known illustration of the immigration of plants. Charles Darwin, on the voyage of the *Beagle*, visited the island of St. Helena in the year 1836. He wrote 'that the number of plants now found on the island is 746, and that out of these fifty-two alone are indigenous species.' The immigrants, he said, had been imported mainly from England, but some from Australia, and, he continued, 'the many imported species must have destroyed some of the native kinds, and it is only on the highest and steepest ridges that the indigenous flora is now predominant.'

Set yourselves to write a geography of Australia as Australia was when first made known to Europe, and compare it with a geography now. Suppose Australia to have been fully discovered when Europeans first reached it, but consider the surface then and the surface now, and the living things upon the surface then and now. Will not man be found to have been a geographical agency? How much waste land, how many fringes of desert have been reclaimed? The wilderness has become pasture land, the pasture land is being converted into arable. The Blue Mountains, which barred the way to the interior, are now a health resort. Let us see what Sir Joseph Banks wrote after his visit to Australia on Captain Cook's first voyage in 1770. He has a

chapter headed 'Some Account of that part of New Holland now called New South Wales.' New Holland he thought 'in every respect the most barren country I have seen'; 'the fertile soil bears no kind of proportion to that which seems by nature doomed to everlasting barrenness.' 'In the whole length of coast which we sailed along there was a very unusual sameness to be observed in the face of the country. Barren it may justly be called, and in a very high degree, so far, at least, as we saw.' It is true that he only saw the land by the sea, but it was the richer eastern side of Australia, the outer edge of New South Wales and Queensland. What animals did he find in Australia? He 'saw an animal as large as a greyhound, of a mouse colour, and very swift.' 'He was not only like a greyhound in size and running, but had a tail as long as any greyhound's. What to liken him to I could not tell.' Banks had a greyhound with him, which chased this animal. 'We observed, much to our surprise, that, instead of going upon all fours, this animal went only on two legs, making vast bounds.' He found out that the natives called it kangooroo, and it was 'as large as a middling lamb.' He found 'this immense tract of land,' which he said was considerably larger than all Europe, 'thinly inhabited, even to admiration, at least that part of it that we saw.' He noted the Indians, as he called them, whom he thought 'a very pusillanimous people.' They 'seemed to have no idea of traffic'; they had 'a wooden weapon made like a short scimitar.' Suppose a new Sir Joseph Banks came down from the planet Mars to visit Australia at this moment, what account would he give of it in a geographical handbook for the children of Mars? He would modify the views about barrenness, if he saw the cornfields and flocks and herds; if he visited Adelaide, he would change his opinion as to scanty population, though not so, perhaps, if he went to the back blocks. He would record that the population was almost entirely white, apparently akin to a certain race in the North Sea, from which, by tradition, they had come; that their worst enemies could not call them pusillanimous; that they had some ideas of traffic, and used other weapons than a wooden scimitar; and he would probably give the first place in animal life not to the animal like a greyhound on two legs, but to the middling lamb, or perhaps to the ubiquitous rabbit. Australia is the same island continent that it always was: there are the same indentations of coast, the same mountains and rivers, but the face of the land is different. In past years there was no town, and the country was wilderness; on the surface of the wilderness many of the living things were different; and from under the earth has come water and mineral, the existence of which was not suspected. A century hence it will be different again, and I want to see sets of maps illustrating more clearly than is now the case the changes which successive generations of men have made and are making in the face of Australia and of the whole earth.

More than half a century ago Buckle, in his 'History of Civilisation,' wrote: 'Formerly the richest countries were those in which Nature was most bountiful; now the richest countries are those in which man is most active. For in our age of the world, if Nature is parsimonious we know how to compensate her deficiencies. If a river is difficult to navigate, or a country difficult to traverse, an engineer can correct the error and remedy the evil. If we have no rivers we make canals; if we have no natural harbours we make artificial ones.' These words have a double force at the present day and in the present surroundings, for nowhere has man been more active as a geographical agency than in Australia; and not inside Australia only, but also in regard to the relations of Australia to the outside world.

An island continent Australia is still, and always will be, on the maps. It always will be the same number of miles distant from other lands; but will these maps represent practical everyday facts? What do miles mean when it takes a perpetually diminishing time to cover them? Is it not truer to facts to measure distances, as do Swiss guides, in Stunden (hours)? What, once more, will an island continent mean if the sea is to be overlooked and overflown? The tendency is for the world to become one; and we know perfectly well that, as far as distance is concerned, for practical purposes the geographical position of Australia has changed through the agency of scientific man. If you come to think of it, what geography has been more concerned with than anything else, directly or indirectly, is distance. It is

the knowledge of other places not at our actual door that we teach in geography, how to get there, what to find when we get there, and so forth. The greatest revolution that is being worked in human life is the elimination of distance, and this elimination is going on apace. It is entering into every phase of public and private life, and is changing it more and more. The most difficult and dangerous of all Imperial problems at this moment is the colour problem, and this has been entirely created by human agency, scientific agency, bringing the lands of the coloured and the white men closer together. Year after year, because distance is being diminished, coming and going of men and of products is multiplying; steadily and surely the world is becoming one continent. This is what I want geographers to note and the peoples to learn. Geographers have recorded what the world is according to Nature. I want them to note and teach others to note how under an all-wise Providence it is being subdued, replenished, recast, and contracted by man.

MELBOURNE.

FRIDAY, AUGUST 14.

The following Papers were read :—

1. *Australian Rainfall. By* H. A. HUNT, *Commonwealth Meteorologist.*

The main factors to be considered in relation to the controlling causes of rainfall in Australia are the south-east and westerly trade winds, the monsoonal and southern depressions, cyclones from the north-east and north-west tropics, locally formed cyclones, and the anticyclones, in conjunction with the modifying effects on these various atmospheric movements of the physical features of the different parts of the country.

Around the central dry area of Australia the isohyets describe somewhat concentric curves, the modifications being mostly due to variations in elevation. Thus, the Darling Ranges to a great degree account for the rainfall of the south-west corner of the continent. The Flinders Range (South Australia) and Australian Alps in the south-east have a heavier rainfall than the surrounding tracts owing to their cooling effect on the air-currents. Along the eastern elevated margin of the Commonwealth the ridges between large river-valleys also account for an enhanced precipitation. Examples of the latter type are the Peak Range and Darling Downs in Queensland, where the eastern ranges of the northern parts of that State obstruct the south-east trade winds and cause our heaviest rainfall. In Western Tasmania there is an excessive rainfall for similar reasons, though there the westerly trades are the moisture-laden winds.

During the hotter months, November to April inclusive, the northern parts of Australia are wet and the southern dry, and in the colder months, May to October inclusive, the southern parts are wet and the northern dry, while over the eastern areas of the continent the rainfall is distributed fairly generally throughout the year.

The southern portions of the continent, where the precipitations are controlled by the 'stormy westerlies,' southern cyclones and V-shaped depressions, enjoy very consistent annual totals, but north of the tropics, and in fact in all parts of the continent subject to monsoon rains, the departures from the normal are occasionally very great.

When the monsoonal disturbances are in evidence, the effect of the rainfall on the country generally and the economic results for the succeeding season are very pronounced. The interior of the continent becomes transformed. The plains, which ordinarily have an intensifying effect on the heat winds of the summer, are deluged with rain, and respond immediately with a luxurious growth of grass and herbage. The air is then both tempered in heat and loses its dryness for considerable periods.

The monsoon region comprises the whole of Australia north of the Tropic of Capricorn, together with Southern Queensland and the north of New South Wales. The heaviest rains are in January and February. They are directly

due to the indraught caused by the heating of the centre of the continent. This leads to the formation of a low pressure in Northern Australia, and the ascending winds are cooled and deposit their water-vapour in heavy rainstorms and thunder showers.

Tropical depressions when well developed are productive of good inland rains, and are evidently caused by southward flows of the atmosphere of wide extent and considerable depth. The 'Antarctic' disturbances are, however, the more frequent in winter. The heaviest totals from this last-named source are precipitated on the west coast of Tasmania. Thus at Mount Lyell the total for one year exceeded 140 inches, and even the average is 116·05 inches. When an 'Antarctic' is supplemented by a 'trough' extending well into the northern interior, it brings much rain to the inland areas of South Australia, Victoria, New South Wales, and even Queensland.

Anticyclonic rains occur at all times of the year, but more markedly from March to September. They benefit particularly the southern area of the continent, and are responsible for many of the heaviest rainfalls and floods on the coastal districts of New South Wales.

Flood rains occur at infrequent intervals over various portions of the Commonwealth, principally in Queensland, the south-eastern parts of the continent, and the northern regions of West Australia.

Typical instances of floods in South-eastern Australia are (1) the flood which occurred in January 1910 in the Upper Darling tributaries, consequent on abnormally heavy rains on the north-western plains and slopes of New South Wales, as well as on the Darling Downs of Queensland.

These exceptionally heavy, continuous rains were caused by the joint action of an anticyclonic area over the southern regions and a monsoonal depression operating in the northern half of the continent. A monsoonal tongue developed and extended southwards over Queensland and New South Wales, while at the same time the energy of the high pressure in the south increased. In five days large areas in the two States had from 5 inches to 19 inches of rain. The enormous amount of water which fell over approximately 86,000 square miles of country may be roughly estimated at thirty-one billion, six hundred and eighty-seven million (31,687,000,000) tons, or seven thousand one hundred billion (7,100,000,000,000) gallons.

(2) A similar development occurred in March of the present year, when a monsoonal tongue extending southwards across the continent against an intensified anticyclone in the south was accompanied by severe thunderstorms and torrential rains. Some of the heaviest individual falls were in New South Wales; *e.g.*, Taralga on the Central Tablelands 10·74 inches, Sydney 8·49 inches, Parramatta 16·91 inches, and Beecraft 18·84 inches in the metropolitan area, and Wollongong 25·34 inches, on the south coast. The barometer readings at Sydney ranged from 30·13 inches to 29·97 inches during the five days the storms were in progress, while the anticyclone to the south gradually gave way simultaneously, the centre (30·4 inches) moving slowly over the southern parts of Victoria and Tasmania eastwards to the South Pacific Ocean.

The wettest known place in Australia is Innisfail, on the north-east coast of Queensland, where the average rainfall for twenty-one years is no less than 145 inches, the maximum yearly total being 211·24 inches, and the minimum 69·87 inches.

The driest region so far furnished with rain gauges lies east and north-east from Lake Eyre, where less than 5 inches is the average annual rainfall, and where a total of 10 inches is rarely recorded during the twelve months. This minimum rainfall is coincident with the lowest elevation, Lake Eyre being actually below sea-level 39 feet.

The inland districts of Western Australia have until recent years been regarded as the driest part of the Commonwealth, but authentic observations taken during the past decade at settled districts in the east of that State show that the annual average is from 10 to 12 inches.

In comparing the rainfall of the chief cities of the rest of the world [1] with

[1] Amsterdam, Athens, Berlin, Berne, Bombay, Brussels, Budapest, Buenos Ayres, Calcutta, Cape Town, Chicago, Christiania, Colombo, Constantinople, Copenhagen, Dublin, Edinburgh, Genoa, Hong Kong, Johannesburg, Lisbon,

those of Australia, it is found that Bombay, Calcutta, Colombo, Singapore, and Hong Kong are the only cities whose rainfall exceeds that of Sydney and Brisbane. Perth has a greater annual rainfall than New York, and more than that of twenty-eight of the forty-two cities used in the comparison. Hobart nearly equals London, which Melbourne exceeds by an inch, while eleven of the forty-two places considered have less rain than Hobart.

The distribution of average annual rainfall over the Commonwealth and the United Kingdom in *thousands* of square miles is as follows :—

	Australia	British Isles
Under 10 in.	1,045	nil
10 in. to 15 in.	652	nil
15 in. to 20 in.	416	nil
20 in. to 30 in.	503	24
30 in. to 40 in.	199	42
Over 40 in.	160	55

The average area under wheat in the United Kingdom during the years 1910, 1911, and 1912 was 1,926,040 acres, and the average yield 59,436,392 bushels; while in the Commonwealth for the same period the area under wheat was 7,379,980 acres, and the average yield 86,243,133 bushels, a difference in the total yield in favour of Australia of 26,806,741 bushels. In Australia wheat-growing under ordinary conditions is generally considered a safe and payable proposition when 10 inches of rain and over falls from the month of April to that of October inclusive. There are in all 484,330 square miles of country with 10 inches of rainfall and over during the wheat-growing period. The output of wheat has been steadily increasing from year to year, and there are vast possibilities of future development in this direction.

The climatic history and prosperity of the last ten years or so contradict emphatically the preconceived notion that Australia is the particular drought-stricken and precarious area of the earth's surface. These misconceptions of the true character of the country have been held in the developmental stages, to a greater or less extent, in the early histories in the majority of all lands and in the colonisation of newly discovered territories; *e.g.*, see history of colonisation of U.S. America and early Egyptian history. The truth of the matter about Australia's rainfall is that (1) it is generally ample for pastoral and agricultural industries over two-thirds of its area; (2) that different regions have distinct seasonal dry and wet periods. These must be more fully recognised and industrial operations adapted accordingly; (3) it is subject in part, but never in the whole, to prolonged periods when the rainfall is short of the seasonal average. Australia is not peculiar in this respect. It follows, therefore, that as the so far undeveloped country becomes populated and put to profitable use, the general wealth of the community as a whole will steadily increase.

A model representing the relative rainfall over Australia has been constructed at the Commonwealth Weather Bureau on a horizontal scale of 133 miles to 1 inch and a vertical scale of 10 inches to 1 centimetre.

It shows at a glance how the annual rainfall is distributed, from the small precipitation over the far interior to the fringe of high rainfall around the greater portion of the coast-line, culminating on the eastern side in a great peak indicating the annual precipitation over the Harvey Creek and Innisfail district, resulting from the prevailing south-east trade winds carrying the moisture against the mountain ranges just inside the coast.

The fringe of relatively high rainfall along the eastern and south-eastern coasts of the continent as the result of the elevated contours near the coast in those regions is also striking.

The effect of the monsoonal rains over Northern Australia is very apparent from the model, which shows the gradual increase of rainfall from under 10 inches in the interior to over 60 inches on the north coast.

The manner in which the prevailing westerly trade winds carry moisture

London, Madras, Madrid, Marseilles, Moscow, Naples, New York, Ottawa, Paris, Pekin, Quebec, Rome, San Francisco, Shanghai, Singapore, Stockholm, Petrograd, Tokyo, Vienna, Vladivostock, and Washington.

along the southern portion of the Commonwealth is clearly marked by the elevations indicating the good rains received over the south-west corner of Australia, and, further eastward, how the ranges east of Adelaide cause good rainfall there and prevent the rain from that direction reaching the inland parts of Victoria.

In Tasmania also is seen the effect of the frequency of the moist westerly winds, causing high rainfall along the mountain ranges of the west coast, with resulting comparative dryness in the eastern parts of that State.

It may be of interest to note in closing that there exists apparently an oscillatory movement of the seasonal rains throughout Australia about a centre in the vicinity of Forbes, in New South Wales. It is perhaps a natural coincidence that this apparent centre of oscillation is approximately the centre of gravity of the Commonwealth's population, and is not far from the Federal capital site.

This peculiar oscillatory character of the monthly march of rainfall suggested the construction of a 'Rain Clock.' In the centre of a piece of cardboard a map of Australia is cut out with a die. At the back of this another piece of cardboard, indicating the rain area, is manipulated on a swivel. By moving the second piece of cardboard backwards and forwards with an amplitude of oscillation of one-fifth of a circle, the land area of the continent affected by dry or wet conditions at any time of the year is approximately indicated.

The immediate lessons to be learned from a study of the 'Clock' are that the seasonal rains are more regular than was generally believed, and that the alternating dry and wet seasons are definitely defined. That being so, when in obedience to physical law there is an absence of rain during the normally dry period in any part of Australia, such dryness should not be regarded as drought, and an evil, but rather as Nature's wise provision for resting the soil.

2. *The 'Mallee' Country of North-Western Victoria.* *By* A. S. Kenyon, *C.E.*

The term 'Mallee,' applied to the scrubby forms of Eucalypt characteristic of the area to be described, is of aboriginal origin.

The Mallee country embraces over 11,000,000 acres and includes the greater part of the north-western portion of the State, over one-fifth of its total area. It is sharply differentiated from other districts by its soils, plants, and general surface configuration.

Surface Formation.—The prevailing feature is the regular occurrence of sand-ridges—of no great height, generally less than 30 feet. They are more or less parallel, running from W.S.W. to E.N.E. With an increase in their height, the soil becomes noticeably poorer; at times they are over 100 feet above the surrounding surface, when the parallelism is almost completely masked and they form a jumble of sand-hills, locally known as 'desert.' More or less extensive expanses of level land with low irregular undulating rises are termed 'broken' country.

Soil.—The soil varies from rich red clayey loams in the 'broken' country to pure white sand in the 'sandhills,' and, except in the latter class, is all suitable for agriculture. Limestone nodules occur almost everywhere, in places becoming almost massive; outcrops of tertiary agglomerated ferruginous sandstone are plentiful. Salt lakes, generally in the vicinity of the more extensive limestone beds, accompanied with 'copi' or gypsum earth deposits, are numerous. These have rarely any inflow of water, and their saltness in every case may be put down to upward filtration. Swamps and terminal lakes without any outflow are, however, generally fresh. The 'broken' country occupies about 20 per cent., the sand-ridges cover 50 per cent., while the sand-hills account for less than 30 per cent.

Plants.—The sand-ridge country is densely covered with *E. Dumosa* and its varieties. Broom-bush (*Bœckea*) marks the transition stage into sand-hills with their desert types of *Casuarina, Callitris, Grevillia, Hakea, Melaleuca,* and *Epacris.* The 'broken' country has large mallee, big pines (*Callitris robusta*), buloke, and belar (*Casuarina luehmanni* and *lepidophloia*), sandalwood (*Myo-*

porum platycarpum and *Eremophila longifolia*) and a great variety of shrubs (*Heterodendron*, *Fusanus*, *Pittosporum*, acacias, &c.), forming probably the most park-like country in Australia. The so-called spinifex, *Triodia irritans*, the porcupine-grass of the settlers, prevails throughout. Salt-bush plains comprising a large number of the Chenopodiaceæ vary from a few to many thousand acres. Grasses are of the tufty, tussocky order, and rarely form a sod or sole of grass sufficient to prevent sand-drift.

Climate.—The Mallee is arid. Its rainfall varies from 19 to a little under 11 inches per annum, averaging 14 inches. In summer the days are intensely hot and the air excessively dry; consequently there is frequently a considerable drop in temperature at night-time, the range being over 70° F. In winter, the days are bright and sunny with much frost at night, temperatures going commonly below 20° F. Cyclones of destructive force are rare.

Geology.—The surface soils are almost wholly æolian or wind-redistributed; this formation extends to 30 feet and over in depth. They have been formed from lacustrine clays and drifts, which are some 200 feet in thickness. Below these beds, enclosed above and below by estuarial blue clays containing broken shells, foraminifera, glauconite, &c., are extensive marine formations, polyzoal and shell rocks of about the same thickness as the overlying lacustrine beds. Below these are terrestrial fluviatile deposits containing much lignite and pyrites. The thickness of these, which rest upon palæozoic, silurian, or granite beds, is variable, reaching 700 feet. The sequence of beds shows in the Tertiary period a considerable subsidence followed by elevation. While the elevation was in progress and the sea had retreated, the streams at present joining the Murray River flowed in and formed the lacustrine deposits until, uniting forces, they cut a canyon through them to the sea. The Murray River canyon has a depth of 60 to 200 feet, and a width of 1¼ to 4 miles. A distinct folding in the whole series of Tertiary beds has been shown by the borings. At the surface these folds are many miles in width and are over 200 feet in height and have a direction a little west of north—at right angles to the sand-ridges—with a marked easterly dip. It is not unlikely that the salt and gypsum areas above referred to mark the synclines, where fracturing allows escape of the artesian waters of the coral marine beds.

Settlement.—There are at present five and a half million acres under settlement, of which about one and a half million acres are under cultivation annually, supporting a population of over 40,000.

3. *The Experimental Demonstration of the Curvature of the Earth's Surface.* By H. YULE OLDHAM, M.A.

4. *The Central Highlands and 'Main Divide' of Victoria.* By T. S. HART, M.A., B.C.E., F.G.S.

A belt of highlands extends through almost the whole length of Victoria. These consist of a peneplain carved out of Palæozoic rocks, and subsequently elevated in blocks to varying heights and dissected. Remnants of older hills above the peneplain are of minor importance.

On these Palæozoic rocks rest fluviatile and lacustrine deposits of Tertiary age. The fossils and relation to marine Tertiaries further south indicate a position low in the Tertiaries for the oldest of these. The formation of the peneplain may be regarded as early Tertiary. In Southern Victoria worn down Jurassic rocks form part of the peneplain. On the Central Highlands and south of them there are also two series of volcanic rocks, known respectively as the older volcanic (early Tertiary) and newer volcanic (late Tertiary).

The central belt of highlands is outside the limits of the Jurassic coal-bearing sediments and of the marine Tertiaries. This area has been relatively high from Jurassic time onward, and has been much more elevated in Tertiary times than the marine Tertiary area.

The general effect produced by the elevation has been a broad belt of highlands falling away to north and south and higher at the eastern end. In detail

this area consists of numerous fault-blocks, more or less tilted, and unequally elevated, producing original crests and valleys. As the crests of the blocks are often transverse to the east and west trends of the whole highlands, the two ends of a relatively low strip may be occupied by streams flowing to north and south respectively. The main water-parting or Main Divide between the north and south streams varies in its relation to the fault-blocks, being determined in part by crests of tilted blocks, or by relatively high blocks, in part by the position of the Divide at the head of streams flowing in opposite directions in the same low area, and in part by volcanic accumulations.

It is not necessary to suppose a single original Main Divide from which streams flowed directly to the lowlands north and south. On the contrary, there is distinct evidence of a more complex arrangement of the original crests so that some areas had less direct outlets - for example, a well-marked east and west crest south of Ballarat is connected by a meridional ridge east of that town to the Main Divide producing two basins, that of Ballarat, and that of the original Parwan; the present southerly valleys of the Moorabool, Yarrowee, and Smythe's Creek are cut later through this southern crest. The presence of original difficulty-drained areas has probably made alterations in the drainage system easier, both by capture and by diversions after volcanic infilling. Alterations are also facilitated by differential movements after the present drainage system was initiated on the rising peneplain.

The Upper Goulburn has probably been formed by linking by capture of originally distinct basins. The same has very likely occurred in the case of the Yarra. The alterations near Ballarat are largely due to volcanic accumulations.

The Main Divide is sometimes volcanic, as in parts near Ballarat, where it is formed by materials accumulated round several vents.

The actual intrusion of the granitic rocks has taken no part in forming the present Divide. These rocks have moved with the others in block movements. They are evidently more likely to be exposed on the peneplain at places of much elevation prior to its completion. Some of these situations would no doubt continue to be much elevated later.

Some of the boundaries of the granitic areas are fault lines from which the granitic country rises rapidly (Mount Cole, Mount Martha, Arthur's Seat). Some of the Palæozoic dacites also make very prominent hills (Mount Macedon, The Dandenongs). In these cases the hard rocks on the uplifted side still present some considerable steepness due to the original fault-scarp.

5. *A Map of the Environs of Rome of 1547.* *By* Dr. THOMAS ASHBY.

The Vatican Library has, by a recent gift of His Holiness the Pope, come into possession of an important collection of maps and plans. This includes an engraved map of the environs of Rome for a distance of about twenty miles in each direction, on the scale of about two inches to the mile. It bears the date 1547, and is unsigned; but Mr. Horatio F. Browne has discovered the Venetian privilege for it, from which it appears that its author was a Florentine, Eufrosino della Volpaia. It is rather a bird's-eye view than a map, the projection not being accurate, but the details (roads, farms, streams, woods, cultivation, &c.) are very well shown; and it is the largest map of this district known until comparatively modern times. Though it is engraved on six copper plates, and served as the original of Ortelius' map, it has remained unknown until now, and the Vatican copy is unique. Dr. Ashby has written the text to the publication in facsimile made by the Vatican Library in a series which it is now issuing ('Le Piante Maggiori di Roma dei secoli 16° e 17°').

6. *Three Early Australian Geographers, their Work, and how it is Remembered.* *By* CHARLES R. LONG, *M.A., Inspector of Schools, and Editor of the Education Department's Publications, Victoria.*

In Australia, the scope of the geography syllabus, especially that of the State elementary school, is comprehensive, and the time apportioned to the

subject is liberal. Of late years, a feature of the teaching has been the connecting of the physical features of the continent with those who discovered, explored, and named them, and of the towns with their founders and early residents. The map has thus become invested with a human interest that serves to give an attraction to the acquirement of topographical details which it did not formerly possess. This mode of connecting history with geography has also been to the benefit of the former. The strongly established subject, geography, has helped to place the weak subject, Australian history, on its feet. Another effect of adding humanity to geographical nomenclature has been to direct the minds of Australian children, and through them of their parents, to the early Australian geographers. The value to the nation of these intrepid men is rapidly obtaining recognition; and when you add to that recognition the result of the giving over of a day annually on which the exploits of the explorers and pioneers are made the sole topic of instruction in the schools (as is the case in Victoria), you will see that the time is ripe for the erection of historical monuments and for the proper appreciation of those already erected.

Of the many men deserving of recognition at the hands of Australians three stand out prominently, the navigators, James Cook and Matthew Flinders, and the surveyor, Thomas Mitchell. The geographical work of these men was of immense importance to Australia.

There is no record of any visit to the eastern shore of the continent before that of Cook, who charted the coast line for some 2000 miles with an approach to accuracy that astonishes the hydrographers of the present day when they consider the disadvantages under which he carried it out.

Among Australian explorers he is easily first in public estimation, sometimes, indeed, being credited by those whose enthusiasm is greater than their historical knowledge with being the discoverer of the island-continent. Public admiration has been shown in the memorials erected to him. At Botany Bay, where he first landed on the Australian soil, there is a tablet affixed to a rock, and also an obelisk. Sydney possesses a fine statue. At Cooktown, Queensland, where the 'Endeavour' was careened at the mouth of a river that bears its name, is another obelisk, and a tree is still reverently preserved as that to which the ship was tied. An admirer at Bendigo, the 'Quartzopolis' of Victoria, has placed a statue of the great navigator in immediate proximity to the principal Anglican church. And, soon, the St. Kilda Esplanade, Victoria, will be graced by a replica of the fine statue at Whitby, Yorkshire.

Next to Cook comes Captain Matthew Flinders, who did a greater amount of surveying along the coast of Australia than any other man. In 1792 he began it with Bligh in Torres Strait, to which he returned ten years afterwards. In 1795 he ventured forth with his intrepid companion, Surgeon Bass, in a boat south from Sydney, with the result that he was able to show to the Governor, Captain Hunter, a chart that won his admiration. Then, with joyful enthusiasm, he went round Van Diemen's Land (now Tasmania) in the sloop 'Norfolk,' and, after that, from Sydney to Moreton Bay. Lastly, in the 'Investigator,' fully accredited by the Admiralty, he began to chart the coast of the continent. Starting at Cape Leeuwin, he worked his way patiently along the coast to Sydney, and thence to the north-east of Arnhem Land, at which point the rotten state of his ship made it imperative for him to bring his survey to a close. His charts are so good that subsequent surveyors have had little to do in the way of amending them.

The first of Australia's memorials to Flinders was erected in 1841 by the Governor of Van Diemen's Land, Sir John Franklin, who had been a midshipman on board the 'Investigator.' It stands overlooking the fine harbour of Port Lincoln, South Australia. The people of that State have not forgotten the good example then set them. They have erected a monument on Kangaroo Island to commemorate its discovery by Flinders, a column on Mount Lofty for a similar purpose, and to the Bluff, in the Encounter Bay district, have affixed a plate to recall to mind the meeting of Flinders and the French explorer, Baudin. Victorians have recently awakened to a recognition of the debt they owe to the man who spent a week in Port Phillip Bay in 1802, and whose excellent chart was used by the early explorers of their State. On Discovery Day, 1912,

Sir John Fuller, the State Governor, unveiled a tablet affixed to the granite tor at the summit of Station Peak, near Geelong, on which Flinders stood to survey the bay on May 1, 1802. At Western Port there is a cairn and tablet which were unveiled by his Excellency the following Discovery Day. It commemorates the discovery of that inlet by Bass in 1798, and the first passage of the Strait by him and Flinders later in the year. Lastly, led by the members of the Victoria Branch of the Royal Geographical Society, an effort that will soon be consummated was set on foot some time ago to erect a worthy statue of Flinders in Melbourne.

Thomas Mitchell, who was appointed Surveyor-General of New South Wales in 1827, had seen service with Wellington throughout the Peninsular War, and had been allowed by him to employ his talent for military sketching and plan-making. To this fine training was added a love for his work as a surveyor and explorer, together with much energy. He well deserved the knighthood that was bestowed upon him. Before his death at Sydney, in 1855, he had recorded a vast amount of detail in connection with the physical features of Eastern Australia.

Of his four great expeditions—the first to the north of New South Wales, the second to the Darling near Bourke and then down that river, the third through Western and Central Victoria (his Australia Felix), and the fourth into Central Queensland—the third proved of inestimable service to the young colony by attracting settlers to it. This fact is now being recognised by Victorians. With the Discovery Day celebrations has been associated the unveiling of a tablet to his memory at Pyramid Hill, where he stood on June 30, 1836, and surveyed the charming prospect around him: of a second on Mount Arapiles, which he ascended on July 23; and a third at Expedition Pass, through which he journeyed on September 29. Owing to the enthusiasm teachers are showing in the matter, it is certain that, in the near future, his line of march in Victoria will be well indicated by tablets.

TUESDAY, AUGUST 18.

Joint Discussion with Section C on the Physiography of Arid Lands. See p. 363.

WEDNESDAY, AUGUST 19.

The following Papers were read:—

1. *Australian Exploration.* *By* the Right Hon. Sir JOHN FORREST, G.C.M.G.

2. *Forest Climate and Rainfall.* *By* E. A. MACKAY.

3. *Recent advances in the Map of the World on the Scale of* 1:1,000,000. *By* Professor A. PENCK.

The proposal for an international map of the world on a uniform scale has been considerably advanced in the last few years. A conference of delegates of several States held in London in 1910 approved the general scheme adopted by various Geographical Congresses since 1892—namely, the scale of the map to be 1 : 1,000,000, each sheet to be plotted on its own surface and to be limited by parallels at a distance of 4 degrees in latitude and by meridians at a distance of 6 degrees in longitude, the meridians to be reckoned from Greenwich, the map to be a hypsometrical map, the contour lines of which should be given in hundreds of metres. The resolutions of the London conference were carried

out by several States, and maps after the scheme proposed were prepared by Great Britain, France, Italy, Spain, the United States of America, Argentina, Chile, Japan, and in Portugal and Hungary. Much work has been done for the map also in Sweden. At the International Geographical Congress of Rome, 1913, it was seen that these maps showed many differences in their methods and execution, and the Congress recommended a second international conference of delegates of States. This conference was held in Paris in December 1913; the number of States represented at it—34—showed how general the interest in the map had become. The resolutions adopted did not alter the general scheme of the map, but settled many of its minor features.

In Australia the scheme was discussed in 1912 by a conference between the surveyors-general of the different States, and its execution was recommended to the Commonwealth. A map on a uniform but not too small a scale would indeed be of the greatest value to Australia, for there is none at present. The different States have hitherto only maps of their own territory, and these maps are unequal as to scale and contents. One feature is common to all—they do not lay stress upon the representation of morphological features, and our knowledge of the extent and height of the physical regions of Australia is limited. In order to extend the international map of the world to Australia extensive surveys are still necessary. It would be an important result of the scheme for a uniform map of the world if it should excite interest in the hypsometrical surveys of Australia.

SYDNEY.

FRIDAY, AUGUST 21.

The following Papers were read:—

1. *The Development of the Natural Order Leguminosæ—A Study in Palæogeography. By* E. C. ANDREWS, *B.A., F.G.S., Geological Surveyor, New South Wales.*

A study of Leguminosæ indicates that the final separation of Australia from Tropical Asia took place before that of Tropical America from Tropical Africa.

This problem admits of comprehension only by a knowledge of the succession of geographies in post-Jurassic time, the character and home of the primitive types of the Order, the soils and climate which various legumes favour, the principles of plant dispersion by sea and land, as well as the arrest of development in certain types, and the wonderful vitality in others, such as Acacia and Astragalus; these principles are all elaborated in the main discussion.

Geography.—Extensive and low-lying plains of erosion, large epicontinental seas, and genial climate, were features of the Cretaceous geography, while large continents, great deserts, small epicontinental seas, high mountains, glaciated poles, and a general differentiation of climate into zones are characteristic of modern geography.

Primitive Types.—Home, the fertile tropics. Trees or shrubs, of luxuriant habit. Leaves simple, sometimes digitate or simply pinnate. Corolla regular, petals five. Stamens definite, five or ten, free, sometimes indefinite. Style simple, peculiar. Fruit a pod or drupe.

The narrow belt of tropical land extending south of the Equator from Tropical America to Australia, by way of Tropical Africa, Madagascar, and Malaysia, was broken up at its eastern end in Upper Cretaceous time, and, still later, it was broken in its central and western portions. Many remarkable groups of genera were developed from the fertile tropical types as the result of the severe climatic conditions and poor soils of Australia, South Africa, and Eurasia. Most remarkable of these are, in the first place, the Podalyrieæ of Australia and South Africa, which were derived from the tropical Sophoreæ; secondly, the Genisteæ of Australia, South Africa, and Eurasia; thirdly, the Galegeæ of Eurasia; and fourthly, the Acacias of Australia, Africa, and America.

Comparisons of these xerophytic forms indicate that, region for region, they are only indirectly related to each other by intermediate forms to be found in

the tropics. For example, the Podalyrieæ of Australia, South Africa, and the Northern Hemisphere are related to each other through Sophoreæ. The Eurasian types have been dispersed, during late geological time, to North America by way of North-eastern Asia, and thence along the high western plateaus to South America.

Antiquity of Isolation of Australia.—Great genera, such as Mimosa and Calliandra, are absent from Australia but are present in America, Africa, and Asia. The peculiar group of the Australian Podalyrieæ, comprising nineteen endemic genera and about four hundred species, also speaks eloquently of the long separation of Australia from Asia. The history of Acacia also may be summarised in this connection. The genus is divided into Gummiferæ, Vulgares, Filicinæ, Pulchellæ, Botryocephalæ, and Phyllodineæ. Species 700. The Gummiferæ are the primitive type, and are well developed in America, Africa, and Asia, only poorly represented in Australia and quite absent from Europe and New Zealand. They represent the xerophytic modification of a luxuriant Cretaceous plant, with bipinnate leaves, even at a time when the great continents were connected by way of the tropics. The Vulgares are the most important types, numerically, in extra-Australian areas, being abundant in America, Africa, and Asia. They are absent from Australia. The Filicinæ belong to Tropical America. The Pulchellæ and the Botryocephalæ are endemic in West and South-East Australia respectively. The Phyllodineæ, with about 420 species, are Australian. Of these the Uninerves represent the earlier type, and are characteristic of poor, sandy soils. The home was Northern Australia. In the early stages the phyllode was narrow with the midrib forming the greater portion. The Pleurinerves appear to be modified Uninerves. Both types gradually pushed their way into the deserts, into West and South east Australia, and into Tasmania. The Uninerves established themselves strongly in the cooler regions of the south, while the Pleurinerves, with the Julifloræ, lagged behind and entrenched themselves securely in the tropics. Both during, and subsequently to, the formation of the great plateaus of Eastern Australia many peculiar phyllodineous types were developed, such as the Racemosæ and the Tetrameræ, and these, in part, during the later glacial period, moved northwards along the plateaus as far as South-eastern Queensland; others again adapted themselves to subarid inland conditions. The endemic Botryocephalæ, also, are in the main a response to plateau development in South-east Australia during later and post-Tertiary time. The western alluvial plains of Eastern Australia, formed during late and post-Tertiary time, gave rise to groups of the Pleurinerves, such as the Microneuræ.

In conclusion, Australia has been isolated from Asia for a great period, and the Leguminosæ of the fertile tropics of the island continent are not comparatively recent and derivative, as has been stated, but are examples of types once cosmopolitan, whose development has long been arrested while the great majority of the endemic types are younger and vigorous xerophytes induced by the altered geographical conditions.

2. *Eastern Australian Topography and its Effect on the Native Flora. By* R. H. CAMBAGE, *F.L.S., &c., Chief Mining Surveyor, New South Wales.*

The chain of mountains known as the Great Dividing Range extends throughout the length of Eastern Australia at distances varying from about twenty to nearly three hundred miles from the coast line. It consists of an uplifted dissected plateau ranging from about 1,500 to 7,300 feet above sea level, the generally lower portions being in Queensland, and the higher in southern New South Wales and Victoria. In general the eastern face is fairly steep and high, and exercises more influence in differentiating the humid climate of the east from the drier climate of the west, than does the actual water-parting itself, which is often only a slight ridge in various positions on the plateau. The effect of the mountains in the south is to create three climates, a humid and dry one on the east and west sides respectively, and a cold one on the summit which acts as a barrier between two floras which would otherwise commingle to some extent at lower levels.

In Queensland a generally lower summit of the plateau, and an increase in temperature owing to the more northerly position of the range, permit the western or dry influence to cross the mountains in various places, and allow many interior types of plants to thrive on the eastern watershed, while the moist-loving or coastal brush plants are excluded from these invaded areas. This invasion occurs in the Goulburn River valley near Cassilis in New South Wales, and at such places in Queensland as between Toowoomba and Brisbane, between Jericho and Rockhampton, and at other points. Where such a mountain passage occurs the moist-loving eastern flora in no case passes through to the west, but in certain instances arrives there by other agencies, and finds congenial surroundings on secluded portions of elevations protected from the west.

The absence of a high range extending along behind the coastal belt in Northern Australia is considered to largely account for the absence of rainfall in that locality during the winter months, and for the sparseness of the brush or jungle vegetation.

The observations in regard to the effects of topography on the native flora indicate that the rainfall and climate in Eastern Australia are very largely regulated by the physiographic features, and the vegetation, after allowing for differences of soils, is chiefly the result of rainfall and climate. It would therefore appear that the removal of the forests would not result in a greatly reduced rainfall, but would probably decrease the number of damp days.

3. *A Recently Discovered MS. by* James Cook. *By* H. Yule Oldham, *M.A.*

4. *The Coast of New Caledonia. By* Professor W. M. Davis.

5. *Southern Alaska and the Klondyke. By* Professor Elwood S. Moore.

6. *Australia: its Discovery as evidenced by Ancient Charts. By* Geo. Collingridge, *Corresponding Member of R.G.S.A., &c.*

1. Early voyages by the Portuguese and Spaniards in Australasian waters, made between the years 1511 36, but not recorded.
2. Reasons for not recording said voyages.
3. Australia named Java Mayor.
4. Discovery, by author, of Portuguese legend on Dauphin Chart
5. Reasons for distorting charts.
6. Western Coasts of Australia discovered by the Portuguese.
7. Eastern Coasts of Australia discovered by the Spaniards.
8. Main features of discovery.

TUESDAY, AUGUST 25.

Joint Discussion with Sections C, D, and K on Past and Present Relations of Antarctica in their Biological, Geographical, and Geological Aspects.—See p. 409.

The following Papers were then read:—

1. *Geodetic Surveying in New South Wales and some Results. By* T. F. Furber, *F.R.A.S., &c., Director of Trigonometrical Surveys, New South Wales.*

The above Paper describes in general terms the limits reached up to the present by the Trigonometrical Survey of the State named, the methods fol-

lowed and the order of precision attained, more detailed treatment being confined to three matters which are engaging attention at the present moment, viz., the general question of periodic errors of instrument graduation; the relation between the height of an observed ray above ground surface and the coefficient of refraction; the third matter being a preliminary comparison of the geodetic with the astronomical latitudes, longitudes, and azimuth, for the purpose of *estimating the relative forms of the surface covered by the survey and that of the assumed spheroid of revolution.*

The survey extends between latitudes 30° and 37° south and longitudes 145° and 153° east, roughly including an area of 100,000 square miles. The fundamental object of the survey as a whole is to provide the positions of a series of points of sufficient accuracy to control the detail surveys made for the purposes of land alienation and administrative surveys generally and at the same time to facilitate map construction. Throughout the work, however, the necessity has been kept in view of observing certain chains of the triangulation with the greatest precision attainable not only so as to strengthen the remainder but to afford data for incorporation with other similar surveys in determining earth dimensions. It is this primary triangulation which the paper deals with.

Base lines have been measured at Lake George and at Richmond, and the Paper refers to the need for further bases of verification owing to the extension of the survey. In preparation for measurement of these, invar tapes have been lately obtained and standardised and the site of one further base (nineteen miles in length) determined on. The angle work has till recently been observed with theodolites (Troughton & Simms) of eighteen inches diameter read by four micrometers, but a 270 millimetre Repsold of the type used in the Geodetic Survey of South Africa has now been installed. For minor details of the methods of observing and reduction the Paper refers to one read by the writer in 1898 to the Australasian Association for the Advancement of Science, the methods there described having been continued. It will suffice here to state that the mean closing errors of the 171 primary triangles is $\pm$ 0″·70 and that applying Ferrero's criterion $\left[m = \left(\frac{\Delta}{3n}\right)^{\frac{1}{2}}\right]$ the value of m is ascertained to be $\pm$0″·54, which indicates that the work is of a high order of precision.

The purchase of the Repsold theodolite necessitated an examination of its circle errors which has resulted in a general discussion of such errors. This it is thought may be of interest and has already caused consideration to be given to the possible need for a change of observing routine. As already mentioned instruments read by four microscopes have hitherto been used. The Repsold is read by two microscopes. The mean reading of two opposite microscopes is affected by periodic errors, $\rho_1 \sin(2\theta + \epsilon_1)$ . . . . $\rho_r \sin(2r\theta + \epsilon_r)$, θ being the circle reading. If after an arc 'Circle Left' the telescope is turned over and swung through 180 degrees horizontally to prepare 'Circle Right' the mean bearing of a signal derived from the combined observations will remain affected with these periodic errors. It is the practice on the survey to use five settings of the horizontal circle, each differing from the preceding by 36°. The new instrument has furnished results showing the large range of 4″ amongst its bearings derived from the different settings. Although the means of bearings derived from the five settings are free from periodic error (other than those involving 10θ, 20θ, ... , it has nevertheless been desired to determine accurate expressions for these errors for various reasons, and particularly with a view to estimating the accuracy of the graduation of the horizontal circle. An analysis shows how expressions for these errors may be determined from the observations of horizontal angles. From observations made at trigonometrical station Rocks to 23 beacons the value $-2''{\cdot}19 \times \sin(2\theta - 55°)$ has been derived for the first term, while from others at station Ovens to 17 beacons the value found is $-2''{\cdot}11 \sin(2\theta - 53°)$. The terms containing 4θ and 6θ seem to have an amplitude of 0″·3 or 0″·2. Combining all the results yet available the correction to a microscope reading of the horizontal circle is, as far as has been determined, $-17''{\cdot}4 \sin(\theta + 101°) - 2''{\cdot}2 \sin(2\theta - 54°) - 1''{\cdot}0 \sin(3\theta + 228°)$. . . . There is no suggestion in this series that the amplitude of the term containing $10\,\theta$ is of any importance, and it is highly probable that the five

settings of the circle are quite sufficient to eliminate in their mean all appreciable periodic errors.

In the paper already mentioned as having been read to the Australasian Association in 1898 the writer referred to an apparent connection between the heights of the lines above the intervening surface and the values for the coefficient of refraction derived from the reciprocally observed zenith distances. The extension of the survey since 1898 has given further data which generally bear out the conclusions then derived. These data and the results are dealt with in the present paper. In the absence of a topographical survey from which to ascertain the height of each line above the intervening surface the observations have been grouped in the order of length of line, the assumption being that generally the longer lines are the higher. Another grouping has been made in which account has been taken of the height above sea-level on the assumption that the higher regions are the more hilly and that there the height of the ray above surface is the greater. Both groupings would seem to indicate that where information as to the highest above surface is lacking varying coefficients of refraction may be assumed according to the lengths of the lines observed. Diagrams are given showing the variations.

The survey has been computed from the Sydney Observatory (Lat. 33° 51′ 41″·1 S.; Long. 151° 12′ 23″·1 E.) as origin. A map accompanying the Paper shows the extension of the survey therefrom southerly about 240 miles to the Victorian border, where it connects with the triangulation of Victoria, westerly about 360 miles to the limits of the almost flat country of the interior, and north westerly towards the Queensland border a distance of 240 miles. The map shows also the differences between the geodetic latitudes, longitudes, and azimuths as derived from the assumed earth dimensions (a modification of the Clarke 1880 spheroid) and the corresponding latitudes &c. obtained by astronomical observation. These show the effects of local deflection of the vertical caused by irregular distribution of surface-masses. Broadly, New South Wales may for our present purposes be said to be divisible into three zones, the littoral of from 20 to 60 miles in width rising from sea-level to 2,000 feet in height; at the rear of that plateau 100 miles in width varying from 2,000 to 3,000 feet in height, with mountain masses up to as much as (in the southern extremity) 7,000 feet, and westward of that a more or less gentle western slope to interior plain country. As the result of the attraction of the central elevated mass and of the defect of gravity of the adjacent ocean it would appear that along the coast there is a general eastward deflection of the zenith of about 10″ with a corresponding westward deflection on the western slopes ranging up to as much as 17″, but gradually diminishing as the flat country is reached. In 1898 a general reduction of the data then available was made for the purpose of obtaining an idea how far there was conformity between the actual surface and the assumed spheroid, but the survey was then too much limited to the eastern slopes to afford satisfactory evidence. With the subsequent extensions of the survey, however, a much more useful discussion of the subject is within reach, and it was hoped that by now bases of verification on the outskirts of the work would have been measured, when it would have been possible to reduce the whole work with the object of enabling such a discussion to be made.

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9. *The Sand-Drift Problem on the Eastern Coast of Australia.* By G. H. HALLIGAN, *F.G.S., Inspecting Engineer and Hydrographer, N.S.W.*

The scientific, as well as the commercial, importance of a full knowledge of the direction, volume, and velocity of the movement of sand on the eastern coast of this continent is sufficient warrant for the labour and cost expended upon it by the author during the last thirty years.

There is undoubted evidence of the sinking of the eastern coast of Australia during recent geological time to the extent of 200 to 300 feet, and the natural result was to leave a very uneven shore-line, with many outlying islands, deep bays, and rocky capes. Had there been no ocean current, running parallel to the general trend of the shore, the sand and shingle, resulting from the

disintegration of the land by chemical, meteorological, and mechanical means would, of course, have been distributed by tides and waves, and would have formed sandy beaches in the immediate vicinity of their origin. The form of the beaches in the neighbourhood of granite, basalt, shale, or sandstone would have been readily recognisable; but such conditions do not exist, and the author endeavours to show that the resultant outlines could not assume the contour of the present shore line, but are the natural consequence of a continuous travel of beach material in one direction.

The Eastern Australian current, which first strikes the Australian coast between Hervey Bay and Moreton Bay, has a velocity of from one to two knots, with very little seasonal variation. Some of the salient points on the coast tend to produce eddies, which have the effect of changing the outline of the sandy foreshore and diverting the course of the rivers, but, in the main, the direction of sand-movement below high water must, in consequence of the current, be from north to south.

The effect of the travelling sand impinging upon the islands and reefs, and its accumulation in the *form of banner reefs, hooks, and tongues, &c.*, are described, and the result shown on the accompanying map. The map shows the boundary of the old rocky coast at the time the last subsidence of from 200 to 300 feet took place, and its relation to the existing foreshore. The intervening space is partly or entirely filled with sand of marine origin, although covered in places with several feet of humus, which forms some of the richest land of our coastal area.

On certain parts of the coast the sandy beaches take the *form of the Greek* letter 'Zeta,' the resemblance becoming less as the speed of the current decreases.

The significance of this 'Zeta' curve, in its relation to harbour engineering, has been referred to by the author in another paper, as also the necessity for differentiation between ocean and tidal currents as they affect sand movement at river and harbour entrances.

The volume of sand travelling down the coast has been computed from measurements made at the Clarence River entrance and at Port Kembla, and the effect of varying weather conditions upon the movement is referred to.

Some measurements of the sizes of the sand grains and their geological origin are given, for the purpose of supplying data for comparison with similar areas in other parts of the world.

3. *Central Australia and its Possibilities.* *By* W. H. Tietkens.

That part of Australia to which reference was made lies for the most part between the parallels of 24 deg. 20 min. and 30 deg. 35 min. South Latitude, and between 123 deg. and 133 deg. East Longitude, embracing an area of about 378,000 square miles, considerably greater than the area of New South Wales. This immense area may be described as a sandy depression, in places perhaps not much above sea-level, where the sand hills or sand dunes in some instances may be 100 feet high, and it has been called the 'Dead Heart of Australia.'

So much has been done in reclaiming these so-called desert tracts in other countries that it would be well to turn our attention to the enormous area at our door. These sand-hills occur in confused groupings, also in nearly parallel ridges, but these will not be found to prevail west of 127 deg. East Longitude. West of that meridian, with few exceptions, the country is more level—soil firm and hard loam, nodules of iron-stained gravel, robust vegetation, spinifex, mulga, desert oak, and other Casuarina. The object is to point out from personal knowledge where such schemes of irrigation can be best effected, and which, if carried out, will in time develop and make profitable that which has hitherto been regarded as a desert waste.

Possibilities are suggested from the fact that native wells are sometimes the remains of mound springs. These springs, we learn, are the natural outlet of artesian waters, and from that it would seem that the artesian basin may here be nearer the surface than has hitherto been observed in Australia.

SECTION F. ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION. Professor E. C. K. GONNER, M.A.

MELBOURNE.

FRIDAY, AUGUST 14.

The President delivered the following Address:—

THE subject which I wish to discuss to-day has been determined for me by the circumstances of the present meeting of the British Association and by the trend of modern economic study and research. We are meeting for the first time here gathered together from distant and diverse parts of the world, and in this Section at any rate we shall be discussing problems similar in certain respects in our various countries but unlike in other respects owing to the differences between those countries. It is a fortunate circumstance, because it is largely by means of an interchange of views and experience acquired in such different environments that true knowledge can be surely attained. On the other hand, it can be said, I think, without any exaggeration that of the economic studies of the last twenty years none have been more fruitful in result than those which have dealt with economic development as it has taken place in the past and as it is taking place in the present. Economic laws, which, after all, are but generalisations of the relations between different factors or of the relations which exist between certain causes and certain consequences, are studied increasingly in connection with particular periods, movements, and countries. New forces and new features present themselves, and with their introduction we perceive a change in results. This at once teaches the relativity of many economic maxims and statements and disproves the assumption, which at times some have been prone to make, that all nations and all countries undergo a uniform process of development and respond in a uniform way to any given action or policy. It throws some light, too, upon the nature of these laws. Economic laws are not invalidated because conclusions alter as premises alter. But, on the other hand, such changes necessarily bring with them alterations in the rules laid down for practical guidance.

We come then to consider the particular economic features which characterise countries passing through the early stages of economic evolution during modern or recent times. Such countries, it need hardly be said, stand in a marked contrast to the older countries which surround and confront them and which have all already passed into further and more advanced stages. They differ also in their economic circumstances and this is what needs special emphasis—from those same countries when in the primary stage of growth in the past.

But to bring the matter within the limits of an address it is necessary at the very outset to define a little carefully the scope of the investigation. New countries differ greatly among themselves. Speaking broadly, they fall into three chief groups. There are tropical countries unfitted for white settlement and marked out by their characteristics for a very specialised development. Again, there are countries like some of the States of South America where, owing to particular features attending settlement, or to climatic and other causes, a growth at all comparable to that which has taken place in Western Europe is

retarded if ever practicable. Lastly, we come to lands like Canada a[illegible] and with these may be included the United States, where considerabl[illegible] to the older countries exists alike in antecedents, circumstances, and [illegible] though in each case there are undoubted and specific economic differen[illegible] purpose, therefore, while not wholly excluding from our survey countries [illegible] two former types, to direct your attention in the main to the last-mentioned [illegible] in the hope that by an examination so defined, and a contrast of countri[illegible] this order with the old European nations, some light may be thrown on [illegible] causes underlying the more striking dissimilarities in development.

Before, however, the economic features and differences distinctive of ne[w] countries are dealt with, it may be well to say a word or two as to the gene[ral] course of early economic growth in England and other European countrie[s]. Three features call for particular mention. In their early stages these latte[r] countries were free from any continuous external contact and interference; thei[r] relations with each other and the outer world were slight, or at any rate not such as to fundamentally determine the direction and nature of their develop[-] ment; they had to meet their own wants and to do this by means of their ow[n] resources. Secondly, during this period the nation itself was composed of smal[l] and almost self-subsistent and self-contained groups. Lastly, economic method[s], social ties, and intellectual attainments were on the same plane, being simpl[e] and, as we now should say, backward or primitive.

When we turn, however, to the position of new or young countries e[it]her a[t] the present day or during recent years, we are met at once by features which stand out in significant contrast to those sketched above. Not only are such countries in the early period of evolution, but they are in continuous contact with other countries, and, moreover, with other countries which are in a very differen[t] stage of development. Again, they are young countries, in some instances inhabited largely or wholly by people, in other cases guided and controlled by leaders, modern in every respect and sharing to the full in the science, know[-] ledge, and ideas dominating the older countries. Furthermore, both their socia[l] and their political features are modern; on the one hand, these are not of th[e] type which in the past were associated with the early stage of growth; on the other hand, the countries themselves are much less affected than are older countries at the present day by traditions and customs which, despite their origin in the circumstances of bygone days, still continue to influence the life of the present. In other words, they are less helped or less hindered by habits of long formation. But these somewhat general considerations are but preliminary to a closer and more careful analysis of the particular economic conditions which beset countries now in the early years of growth.

Firstly, such countries, even in the earliest stage, are unavoidably in close relations with countries which have attained a more elaborate growth and organisation: communication renders isolation impracticable, and every year the means of communication increase. It is a question, not of intentional interfer- ence, but of that inevitable influence which nations in close relations bring to bear upon each other. Nor is it a question of one-sided influence. Older nations have been and are affected in their economic policy and organisation by the discovery and opening up of new lands and by the events taking place in them. Still, it is probable that the influence of the older-established world is more powerful, so far at any rate as the direction of economic progress is concerned. Be this, however, as it may, it is this aspect which occupies our attention at the present moment. The effect is particularly apparent in trade and industry. Needs, in other words, are not dependent for their specific satisfaction on the internal resources and productive activities of the particular land, and this, while important in all instances, is of great moment in the case of a country which, as yet without opportunity to develop its powers, is seeking, as it were tentatively, the best lines of advance. It is peculiarly open to influences of this kind, because its organisation is not firmly established. When the social struc- ture is less complete and the direction of development uncertain, the risk of future and permanent advantages being outweighed by present gain is enhanced.

Secondly, in the opening up of resources, the former dependence on the internal powers of the country has been essentially modified. Both capital and labour can be obtained from outside. This, of course, quickens development;

[illegible] .. may affect its direction. Certainly it introduces many [illegible]lems ; and sometimes these are very difficult problems. Taken as a [illegible] leads to a very rapid or sudden development, an aspect of peculiar [illegible]ce where what we call native races are concerned. Quite apart from [illegible] evils often associated with such alien intrusion or dominance, and apart from the shock occasioned by the introduction of foreign standards and [illegible]s alongside of or in substitution for old usages, such people often have [illegible]ifested an inability to stand the mere pace of modern progress. Even when [illegible] come to white races, the results of the rapid progress which occurs when natural resources are rich are open to adverse criticism. Again, it may lead to too great a concentration on particular methods of production and particular occupations, to the exclusion it may be of other methods and occupations which ultimately may be more advantageous. Again, stable customs and social ties are more difficult to form when industrial development is hurried. In addition to these, other special difficulties manifest themselves in the respective cases of alien capital and alien labour in new countries. So far as capital is concerned, the case varies according as the introduction of foreign capital is or is not accompanied by the introduction of those who control the employment of the capital, and so the industries in which such capital is used. Even when alone an interest on the part of outside nations is often awakened which is not wholly healthy, extending sometimes to attempted political influence, though this, it should be said, is not of frequent occurrence except in the case of countries largely native or semi native or occupying a very backward position in the scale of civilisation. Sometimes, too, it may occasion the premature exhaustion of particular sources of wealth, or at any rate rather in the interests of foreign capitalists than of the inhabitants themselves. But in the case of the more backward countries, and especially of countries where climatic conditions preclude a white population occupied in manual work, it has usually meant the introduction of a class, controlling capital and organising industry, and yet entirely alien to the main body of inhabitants. Such a situation undoubtedly imposes a great responsibility on those in whose hands lies the social and political government of the country, a responsibility still greater when the organising class does not settle down, but comes and goes in a bewildering procession. British India and the Dutch Indies furnish illustrations; and, to some extent, the effect of such a tendency is to be perceived in certain parts of South America. Nor is the immigration of labour from other countries less complex or less potent in its results. Such labour comes from many sources and varies greatly in kind. A clear distinction, however, must be drawn between white labour not essentially different from the existing white population and more or less skilled or otherwise adapted to good manual work, and, on the other hand, labour of a lower type, often racially distinct and in some cases brought in owing to its climatic suitability. So far as the former is concerned, immigration as a rule is attended with few difficulties other than those of a simple economic character and more or less temporary in their nature. A ready means of stimulating industrial development is provided, and the country is supplied with skilled adults without the cost of education and upbringing. But the results of immigration of the second type of labour are less simple. The general question of immigration, indeed, may be looked at from three points of view. From the aspect of economic employment, immigration often involves immediate competition with the labour already in the country or coming forward with the normal increase in the population. But in a new and progressive country with many openings for new developments such competition is seldom harmful. In the long run the labour creates its own field of employment and contributes towards the general progress. At times, it is true, the supply may be in excess of the demand, and any particular kind of labour may continue to stream in long after the need for it has ceased. But this can be remedied best by the wider diffusion of accurate knowledge as to the conditions and necessities of the place in question. Positive restriction, if attempted, may do harm by obstructing supplies of labour when needed in the future. When, however, economic standards of living are considered, the kind or type of labour in question is all-important. Ordinary white labour entering a country already peopled with white men offers little difficulty. But nearly all nations have encountered difficulties

when any considerable immigration of labour occurs from countries where the standard of living is essentially and, as it were, permanently lower, and these are rendered graver when accentuated by difference of race. In old and new countries alike the entry of a low type of foreign white labour may bring about a lowering of the general standard in certain industries or certain places, with harm, not necessarily limited to the district or employment in which it settles. Still, apart from the more general considerations of policy, interference would probably involve restriction of the more desirable type of labour already dealt with and thus be economically disadvantageous. The case of coloured labour is admittedly different even in this respect. Standards vary and the racial barrier seems to prevent their speedy adjustment. But the difficulties of the whole matter are shown more clearly if we turn to consider immigration in its relation to general social progress and political government. Here the main point is the possibility of assimilation. How far or how easily, it is asked, can such new elements be absorbed into the general life and made an integral part of a homogeneous population? Now, it is not my business to discuss the question in detail, still less to examine any particular policy which may be advocated or which may have been adopted. All that is necessary is to note this difficulty and to emphasise its existence in the case of new countries and especially of those countries or places where labour of this type is required or attracted by reason of climate or other like causes. Two considerations may come into sharp conflict: on the one hand, the rapid production of wealth may be assisted; on the other hand, serious effects in respect of economic progress, nationality, and orderly growth may be experienced.

In no country, it should be added, has the question of the supply of labour from outside played a more important part in economic history than in Australia. During the early period not only was it one of the influences which tended to the continuance of the transportation system, but it was, if not the chief, one of the two chief factors in the policy of colonisation and settlement devised and advocated by that very distinguished man, Edward Gibbon Wakefield. In more recent years it has been associated with state assistance, and also with forms of indentured labour. And it remains one of the problems before the country.

Thirdly, modern methods and modern science are applied to production even in its early phases, to agriculture and the extractive industries as well as in trade and manufacture. The consequences are both many and great. Rapid and sudden growth is rendered possible, but this, as already indicated, results in consequences not always or wholly advantageous. Such effects are the more evident when the natural resources of the country are rich. Furthermore, when such occurs there is an invariable tendency to substitute large-scale systems of production for the small scale systems characteristic of production in the past when in an early stage, and this is not without significance both economic and political. No doubt this is of greater moment when a development of this order takes place in a land peopled by native races, who are forced, as it were, into a system wholly alien to their social surroundings, and one which they fail to understand. There is a disastrous incongruity between their method of employment and their social environment. Though of less it is still of some importance when the population itself is modern in civilisation and outlook. To some extent, but only partially, they inherit from their ancestors in other lands the lessons slowly acquired in the time of small industry and occupation. On the other hand, there can be no doubt that the more rapid progress due to the reasons given, accompanied as it is by greater vicissitudes, offers a more general opportunity of success to those willing to work hard than is possible in other countries. Rapid progress always tends towards this end, and it does so the more especially when the organisation is more flexible and less marked by custom. Not only is the field itself wider, but the changes in the field are more frequent.

The difference in economic development, thus briefly depicted, implies, it must be remembered, a somewhat parallel difference in administrative and political life. If we take such a country as England, small-scale production was part and parcel of a system in which small local communities grew up practically self-contained and self-governed. Thus the strength of the Government rested largely on local administration which made its influence felt in the

general and central administration. But in a young country developing under modern conditions the system of local administration is consciously devised. It rather derives its existence from the central Government than furnishes the material out of which this latter is gradually evolved.

Fourthly, a modern new country has before it the example of older countries which, after passing through the phase in which it is, have developed the more complex economic system towards which it is tending. Their conditions and institutions record the results of forces which, though nascent in it, are yet in operation. It may have something to imitate, it certainly will see much to avoid. This is true from many points of view. It is true in a technical sense. Everyone knows the importance of ruthlessly scrapping plant: but there are parts of the national plant, as it were, which cannot be scrapped. Though neither the English railways nor the English canals if laid out anew would be constructed on their present lines, they are too elaborate and costly to be destroyed and reconstructed. It is equally, if not more, true when we consider the industrial system in its more general aspects. In this instance we know that Germany, to take an instance, enjoyed one advantage because her development followed, and was not contemporary with, industrial development in England. Perhaps it is truest of all in respect of the social consequences of industrial development. Take, for example, the large cities and manufacturing districts in the old countries with all their social problems: housing, sanitary, and social. A country in the early stages is in this truly advantageous position that action in its case means prevision and not reform. Hence the crucial importance at the present time, in such a country as this, of the Town Planning movement. Again, there has occurred, in those lands in which manufacture has made its greatest strides, a gradual exodus from the rural districts, partly no doubt because of the larger wages to be obtained in the towns and industrial districts, but partly owing to a past, if not present, disregard of agricultural interests, and to the comparative lack of attraction in the country. It may be looking ahead to suggest that such may affect a country like Australia: but time brings many changes. In any case the time to provide against a movement such as this is not when it has acquired force, but when agriculture is prosperous and before town life has begun to exert its curious lure on the population.

Fifthly, older nations became critical and self-conscious at a comparatively late stage in their history: that is, after customs had been formed and structure had lost its former flexibility. In such cases remedial movements and changes, however wisely initiated, encounter a natural and quite comprehensible conservative opposition. Whatever their possible gain, in the progress towards this destruction is involved. Nor is it incorrect to conclude that in many instances the immediate and certain losses rightly outweigh the problematic if ultimate advantages. Far otherwise is the case in a new country where the period of self-consciousness begins with the early days of growth, and conscious action towards a given goal has an easier path and suffers less from the knowledge that it must destroy in order to achieve. Even if social experiments fail, in such countries they cost less than they would in countries more stable and more firmly based in habit and tradition. Of course, there is loss as well as gain in this. In the one type of country there is greater stability, in the other greater confidence or courage in novel directions.

Lastly, and following to some measure on what has just been said, we have to take into account the smaller part played by social conventions in the economic life of new countries. In older countries, primary development took place under conditions as to social life and order not due wholly to economic causes, but often arising from reasons which existed outside that domain. Social position, accepted without question, and forces like caste, rather indicated what various classes were to do than grew out of the necessities or nature of their respective occupations. No doubt some correspondence was required, since regulations unsuited to progress led to the supersession of the races less apt to meet the needs of the time, and so the usages which survived bore the stamp of economic fitness. Still, in the main, economic activities rather followed than created class divisions. But the economic situation changed, and thus in later years we have the curious spectacle of distinctions which have survived from the past and with time lost much of their meaning, lingering on side by side